The University of Adelaide

REPORT

of the

WAITE AGRICULTURAL RESEARCH INSTITUTE

SOUTH AUSTRALIA

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1956-1957

COMMONWEALTH MYCOLOGICAL INSTITUTE
22 JAN 1959

REPORT OF
THE WAITE AGRICULTURAL RESEARCH INSTITUTE

Photograph: Rupert J. Best

The Laboratories at the Waite Agricultural Research Institute of the University of Adelaide, in a setting of growing wheat and native savannah woodland. The red gum (*E. camaldulensis*) in the left foreground is estimated to be about 300 years old.

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The University of Adelaide

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The Waite Agricultural Research Institute

STAFF (at 31st December, 1957)

Director: J. Melville, M.Sc., Ph.D.

Agricultural Chemistry:

Waite Professor of Agricultural Chemistry and Head of Department: R. K. Morton, B.Sc.Agr., Ph.D., F.A.A.

Reader in Soil Science: J. P. Quirk, B.Sc.Agr., Ph.D.

Senior Lecturer:

Virus Chemistry: R. J. Best, D.Sc.

Lecturers:

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Virus Chemistry: H. P. C. Gallus, M.Sc.
Soil Chemistry: D. G. Lewis, M.Sc.
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Analyst: A. C. Jennings, B.Sc.

Laboratory Steward: H. R. J. Lovelock.

Technical Assistants: G. F. Mate, Eleanor E. Johnson.

Laboratory Assistants: M. P. Radic, D. H. Stewart-Jones.

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Plant Breeding and Genetics: K. W. Finlay, Ph.D.
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Agrostology: H. V. Jenkins, B.Sc.Agr.

Lecturers:

Botany: D. E. Symon, B.Ag.Sc.
Agronomy: K. P. J. Barley, M.Agr.Sc., R. J. Millington, M.Sc., Ph.D.
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Lecturers:

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Senior Lecturers:

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Microbiology: J. H. WARCUP, M.Sc., Ph.D.

Lecturers:

Plant Pathology:

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N. C. CROWLEY, M.Sc., Ph.D.
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Plant Physiology:

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L. PALEG, B.A., M.Sc., Ph.D.
D. ASPINALL, B.Sc., Ph.D.

Horticulture: G. R. EDWARDS, B.Sc.Agr., M.Sc.

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Assistant: FAY CAPON.

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Secretary to Director: Laureen G. Downie.

Secretary to Professor of Agricultural Chemistry: Barbara Miller.

Secretary to Professor of Agriculture: Bernadette T. Morrison.

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Clerk: C. S. Leaney.

Photographer: K. P. Phillips, A.R.P.S.

Assistant: Janice M. Oliver.

Farm:

Manager: K. A. Pike, R.D.A.

Technical Assistant: A. W. Dick.

Head Gardener: F. A. Couzens.

Members of the Staff who were Absent on Study Leave during 1956-1957:

N. T. Flentje, R. J. Millington, D. E. Symon.

Fulbright Scholar: J. E. Eckert, M.Sc., Ph.D. (University of California).

Post-Graduate Students: M. S. Buttrose, J. Nath, P. R. Birks, W. R. Stern, L. A. G. Aylmore, J. McD. Armstrong, R. J. Van Velsen, Judy Brown, K. B. Rajbhandary, Hla Aye, H. L. Munasinghe, A. T. Joseph, H. S. Hawkins, R. R. Rawat, R. H. Sedgley, W. J. Lovett.

Members of the Staff who have Left for Other Appointments since January 1, 1956:

J. A. Prescott (Retired), C. S. Piper.

The Waite Agricultural Research Institute

1. Introduction.

The foundation of the Waite Institute was made possible as a result of the gift of Peter Waite to the University of Adelaide of land and property at Glen Osmond, together with an endowment.

The land comprises the Netherby Estate (112 acres) and Claremont (53 acres) adjoining the main estate of Urrbrae, making a total of 299 acres as the original gift to the University for the Institute, in addition to 114 acres to the South Australian Government for an Agricultural High School. The University has since purchased 80 acres of the Springfield estate adjacent to Netherby and 10 acres of Alverstoke for the purposes of the Institute.

Including investments to the value of £58,450, the total value of the gift was estimated at £100,000; the annual Government subsidy of five per cent. amounted to £5,000, and work began with an income of about £8,000.

The first appointments to the staff were made in 1924 and 1925.

The first three laboratories were those endowed by the late Sir John Melrose, the family of the late John Darling, and the family of the late Ranson Mortlock. A fourth laboratory was completed in 1947.

In addition to the laboratories, a range of glasshouses, a cool house for biological work in the summer months, two implement sheds, a woolshed and a cereal barn have been erected since 1925.

Endowments subsequent to the original one of Peter Waite have included those of the late Mrs. Elizabeth Macmeikan, Mr. Hugh Hughes, Mr. W. D. Grigg, and Mr. W. H. Sandland. The Ranson Mortlock Trust Fund was established in 1936 by the family of the late Mr. Frederick Ranson Mortlock for research in connection with the management of pastoral lands in the more arid regions. Mr. J. T. Mortlock subsequently generously supported these investigations and on his death in 1950 made financial provision for their continuation. Mrs. J. T. Mortlock contributed a further capital sum during 1952.

Apart from its original and subsequent endowments, the Institute derives its main income from appropriations under Acts of Parliament of South Australia.

Since 1927 the Division of Biochemistry and General Nutrition of the Commonwealth Scientific and Industrial Research Organization has maintained at the Waite Institute a field station equipped with feeding pens for the nutrition of sheep under experimental conditions.

Since 1929 the Waite Institute has been the headquarters of the Division of Soils, and since 1935 has housed the Oenological Research Unit of the Commonwealth Scientific and Industrial Research Organization. The latter has recently been reconstituted as the Australian Wine Research Institute, and in February, 1958, moved into new buildings close to the Waite Institute. In the same area there is also under construction for the Division of Soils, a series of new buildings which will ultimately house the whole of the staff now accommodated in the Institute; the Pedology and Chemistry Sections together with the Administration transferred to the first of their buildings in August, 1958.

Under the original deed of gift it was provided that portion of the estate containing an area of 67 acres should be held in perpetuity as a public park. Effect has been given to this provision by the establishment of the Waite Arboretum, in which trees can be grown to demonstrate their value for shelter and ornament, and their adaptability to the local soil and climate. The Arboretum now has 1,300 trees, including varieties belonging to 650 different species (See page 11). The first plantings were made in 1928.

The Library of the Waite Institute is designed to meet the needs of a research staff, and the policy is to make it as complete a reference library as possible on matters relating to agricultural science and its related scientific disciplines. The present total of books is 5,773, and of bound periodicals, 6,735.

The example set by the Wool Industry in supporting research work designed to increase its efficiency is being followed by other sections of primary industry. During 1956-7 the Institute received £16,418 from the Wool Research Fund, in 1957 £3,450 from the Barley Improvement Fund, while a considerable sum will become available from the newly established Wheat Industry Research Fund.

Over the years the Institute has received generous support from the Rural Credits Development Fund of the Commonwealth Bank. During 1956-7 the Bank provided £3,000 towards the construction of an insectary and £25,000 for the establishment of a unit of protein chemistry. The insectary fund has also benefited by gifts received from a number of industrial firms and from the Wool Research Committee. The George Aitken Pastoral Trust has made a grant towards the equipment of a sheep nutrition unit, while Imperial Chemical Industries are supporting research into the control of weeds in cereal crops.

Various benefactors, both private and commercial, are mentioned by name in the foregoing paragraphs but the Institute is indebted to others, too numerous to mention, who have assisted its research programme in a wide variety of ways.

On the retirement of Professor J. A. Prescott at the end of 1955, the Council of the University decided to divorce the directorship of the Institute from the Chair of Agricultural Chemistry. Dr. J. Melville of the Department of Scientific and Industrial Research, New Zealand, was appointed Director in January, 1956, while Dr. R. K. Morton from the School of Biochemistry, Melbourne University, took up his appointment as Waite Professor of Agricultural Chemistry in May, 1957.

2. The Teaching Programmes.

The Institute comprises five University Departments and is the headquarters of the School of Agricultural Science, which offers a four-year course of instruction leading to the degree of Bachelor of Agricultural Science. Teaching during the first two years is given in Science Departments, while the Institute is primarily responsible for teaching in the third and fourth years. The courses given are Agricultural Botany, Agricultural Chemistry, Agriculture, Biometry, Entomology, Horticulture, Microbiology, Plant Breeding, Plant Pathology, and Soil Science. Certain subjects of which the most important is Animal Production, are taken at the Roseworthy Agricultural College.

Honours and post-graduate teaching is undertaken in all departments; in 1956-57 two students were enrolled for the degree of B.Ag.Sc. (Hons.), 19 for the degree of M.Sc. or M.Ag.Sc., and 7 for the degree of Ph.D. These included several candidates from south and south-east Asia.

3. The Research Programme.

The Research Programme of the Institute covers a wide range of scientific disciplines underlying agricultural practices; it is summarised in the following account of the work of the five departments. The Institute also provides specialist advisory services in systematic botany, plant pathology and entomology to the Minister responsible for the State Departments of Agriculture and of Woods and Forests.

The Work of the Institute

Agronomy

As in earlier years a considerable part of the work of the Department has been devoted directly or indirectly to the study of pastures. During the past few years a new aspect of this work has been the study of the competition in pastures, particularly as affected by the leaf area of the sward and its efficiency in the interception of light. It is postulated that light may well be the limiting factor to production under field conditions for at least part of the season in many parts of the world. For example, in the Waite Institute environment, the growth of adequately fertilised subterranean clover during the winter months of liberal water supply, is largely governed by competition among the leaves of the sward for the incident light energy. The maximum rate of growth is attained when the Leaf Area Index (leaf area per unit area of land) reached about 4 or 5, and declines as leaf area further increases. These studies are believed to provide opportunity for a scientific approach to pasture management, which has tended in the past to be an empirical or even mystic field of enquiry.

A second phase of work which has been further developed is the influence of soil aeration and of surface sealing on plant growth. Laboratory and glasshouse studies have been extended to the field, where it has been shown that heavy rains following sowing have affected not only the germination but also the subsequent growth of cereal crops.

Studies continue on the development of adapted perennial grasses in the Mediterranean environment, especially with *Dactylis* and *Lolium* species; this includes both ecological and plant breeding studies. The programme on earthworms has given a satisfactory account of their occurrence and significance in the Adelaide environment, and was concluded in 1957. Work continues on plant nutrient deficiencies in the field and on supplementary feeding of livestock during the dry summer months.

Thus the work of the Department embraces various aspects of the soil-plant-animal relationship.

1. Permanent Rotation Experiment (C1).

This experiment, which was commenced in 1925, and has been supervised throughout this period by Mr. K. A. Pike, includes a comparison of ten systems of crop rotation in which the principal crop is wheat. A permanent plot of sown pasture is also maintained in the experiment.

The mean yields for the period 1926-1957 (both grain and total produce) together with the yields for 1956 and 1957 are given in Tables 1 and 2 on pages 54 to 56. The number of years of record on which long term means are based was standardised for all rotations in the 1952-53 Report. Several rotations, particularly those involving leys, have been in progress only since 1949 and full assessment of their value is not possible at present.

In both the 1952-53 and 1954-55 Reports, the beneficial effects of broader rotations on the yield of wheat was demonstrated. The effects of an excessively wet season in depressing yields was most apparent in 1955. Again in 1956 there

was above average rainfall during the growing season and low yields were obtained for wheat. The broader rotations have in general maintained their superiority. However after a four year ley in Rotation 5 the following wheat crop in 1957 was extremely poor yielding only 1·9 bushels per acre. It is common to experiment C1 and C92 that wheat crops sown directly on to ploughed up long leys (4 and 6 years) have proved unsatisfactory over the treatment period.

2. Investigations on Forage Crops and Temporary Pasture in Four-Course Rotations with Wheat (C53).

The following treatments were on trial to compare the effects of various forage crops and pasture treatments on soil fertility, using wheat as the reference crop:—

1	2	3	4	5
Fallow	Fallow	Fallow	Fallow	Fallow
Wheat	Wheat	Wheat	Wheat	Wheat
Fallow	Oats	Oats*	Peas	Peas
Wheat	Pasture	Pasture	Pasture	Grazing Oats

* With added ammonium sulphate.

The pasture phase in rotations 2, 3 and 4 was Wimmera ryegrass and in 5, grazing oats. Half of each plot sown to forage was harvested each year and the other half plot was grazed by sheep.

Changes were made in the original layout of rotations and the results presented in Table 3 on page 58, are mean values from 1949 and are comparable for all treatments. Yield data for 1956 are given in Table 5 on page 60.

The experiment was discontinued at the end of the 1956 season and no detailed analysis of the experiment will be given here. In all phases of all rotations there has been an apparent decline in yield with time. This can be seen in the table below for three rotations which were maintained for the full course of the experiment.

Rotation	Total dry matter yield cwt. per acre						Grain yield, bush. per acre	
	Peas		Oats		Pasture		Wheat	
	1st 2 cycles	last 2 cycles	1st 2 cycles	last 2 cycles	1st 2 cycles	last 2 cycles	1st 2 cycles	last 2 cycles
Fallow, wheat	—	—	—	—	—	—	31·0	20·0
Fallow, wheat, oats, pasture	—	—	20·9	7·8	10·7	4·8	35·3	26·2
Fallow, wheat, peas, pasture	39·8	18·7	—	—	33·4	17·4	41·6	32·2

Seasonal conditions during the period 1947-1956 were in general wetter than in the earlier stages of the experiment. Nevertheless it is clear that yields of forage and pasture phases over a considerable period of time are both unsatisfactory

and probably still deteriorating. Under the conditions of the experiment Wimmera ryegrass gave extremely low yields in the rotation lacking a leguminous phase. The mean yields of Wimmera ryegrass in the rotation fallow—wheat—peas—pasture were satisfactory during the earlier years but declined markedly in the later stages. The decline in yield of oats was particularly severe.

Although the decline in mean yields was found in all phases of the rotations, it is noteworthy that yield decrease was least in wheat crops. It is clear that the four course rotations used in the experiment do not maintain fertility. The crop yields, which reflect both soil and climatic conditions and their interactions, are low. During the latter stages of the experiment very low yields were associated with above average rainfall and were therefore not due to water stress.

Physical deterioration of the red brown earth soil of the experimental site has been most marked, but little change in the soil nitrogen content has been observed. All rotations in the experiment receive annual cultivation and under these conditions physical degradation of the soil occurs by both mechanical shattering by implements and by rain damage.

In 1955 extensive data were collected and it was shown by Dr. R. J. Millington that yield variation in wheat over the experiment was related to apparent density of the soil. Variation in total nitrogen status was from 0·08% on the fallow—wheat rotation to 0·10% on the four course rotations with peas; total nitrogen status however did not contribute significantly to yield variation. The role of apparent density of the soil as a yield determinant was not related to differences in numbers of plant established; in this year, there was no significant decline in percentage establishment with increase in apparent density over the experiment.

The data showed that in a wet season as in 1955, yield is significantly related to apparent density of the surface soil. Examination of data for previous years showed that apparent density on a single treatment varied between seasons and that total rainfall in the month following seed-bed cultivations could account for this variation.

Seasonal variation in yield then was examined and again on any one treatment the rainfall in the month following seeding could satisfactorily account for a large part of this variation. The differences in apparent density between treatments due to cultural treatment were reflected in the significant separation of parallel regressions of yield on post-seeding rainfall.

Thus apparent density of the surface soil has been identified as a yield determinant. Although this has not been done by controlled experimentation the evidence obtained from rotation trials is both practically and statistically highly significant. With cultural treatments on heavier soils resulting in serious physical degradation of the soil, yields of wheat will be drastically reduced when 3 or more inches of rain occur in the month following seeding. Both apparent density and post-seeding rainfall are determinants of the gas-filled pore space of the soil. The results indicate that impaired soil aeration, at least during the establishment phase, can limit crop growth and yield.

3. Influence of Pastures and Forage Crops on the Yield of Wheat in Rotations of Varying Duration (C92).

This rotation trial was terminated at the end of the 1956 season. The previous Report summarised some of the more important aspects of soil structure and nitrogen fertility differences arising from the treatments.

The treatments imposed were:

(a) Fallow-wheat.
(b) Peas-wheat.
(c) Two years pasture-fallow-wheat.
(d) Three years pasture-wheat.
(e) Six years pasture-wheat-wheat.

The experiment was conducted for eight years and the yield data over this period are summarised in Table 5 on page 60. The effect of an initial two year rest period on the yields from Block I (rotations started in 1949) is shown clearly in the table 5.

More detailed analysis of some aspects of the experiment will be published elsewhere.

The role of soil surface apparent density as a determinant of wheat seedling establishment has again been assessed in this experiment. In any one season there is a variation in apparent density between treatments. Further, for each treatment, there is variation in apparent density between seasons, and as in C53 this variation can be ascribed to the rainfall in the month following seeding.

Dr. Millington collected the seedling establishment and apparent density data for a number of seasons and assessed the influence on establishment of increasing apparent density. If the apparent density of the surface soil exceeds about 1·5 gm per cc, according to seasonal conditions, establishment may be reduced to 10-20% of viable seed sown.

The form of the curve relating establishment to apparent density was similar to a "dosage-mortality" curve indicative of a normal distribution of "resistance" within the wheat population to some factor dependent on apparent density. Mechanical impedance to emergence under high rainfall conditions at any apparent density is not likely to result in reduced establishment. Again the interaction between post-seeding rainfall and apparent density suggests that impaired soil aeration is at least a contributing factor to reduced seedling establishment.

4. Response of Wheat to Applied Nitrogen.

During 1955 and 1956 a survey of some soil conditions in relation to wheat yields was made on experiments C53 and C 92. In addition, applied nitrogen treatments were superimposed on discontinued blocks of C92 to provide further data.

The two major soil conditions considered to limit yield of wheat on the rotation experiments were soil structure and available nitrogen. Soil phosphorus status was found to be high on all treatments. It was hoped to assess the possible limiting role of soil structure by using nitrogen treatments on the range of soil structure resulting from experiment C92. Although surface structure was correlated with total nitrogen status of the soil, it was believed that at high rates of application of nitrogen, the effects of soil structure differences may become apparent.

However no simple relationship was found between apparent density and nitrogen response by wheat. Examination of the data is continuing.

5. Other Soil Fertility Studies.

(a) Further studies have been made by Mr. K. P. Barley on the abundance of earthworms on agricultural land near Adelaide and of their action on the soil. In addition to the lumbricids previously described a megascolecid, *Micro-*

scolex sp., has been found in large numbers under some sown pastures. Enchytraeids have been found on an irrigated pasture. Permanent pastures support about 80g freshweight of earthworms per 1,000g annual production of dry herbage. The ratio ranges from 35 to 110g per 1,000g depending upon the time of the year or the soil type. The weight of worms reaches a maximum in mid-winter. After one year of fallow and one year of crop, the weight of worms is reduced to one quarter of the weight found under pasture.

Dung appears to be an important constituent of the diet of *Allolobophora caliginosa* (Sav.). A population weighing 100g/m^2 ate or drew into tunnels 1g of oven dry dung per m^2 per day even when other foods were available. Chemical changes occurring in the gut have little influence on the supply of plant nutrients. Interactions between earthworms and microbes can, however, increase the rate of decay of dung and dead plant material. The interaction is not completely removed by mixing the leaves or dung pellets with the soil. The tunnels of *Allolobophora caliginosa* (Sav.) and *Eisenia rosea* (Sav.) were not sufficiently abundant within the B horizon of a red brown earth to have any significant influence on the rate of gaseous diffusion within the horizon.

(b) A detailed study of the influence of grass root growth and decay on the porosity and moisture conductivity of a sandy loam has been completed by Mr. R. H. Sedgley. As the roots grew they compacted the adjacent soil and occupied existing voids. Changes in moisture conductivity, which accompanied growth and decay, are shown in the following table.

Changes in moisture conductivity of a sandy loam accompanying the growth and decay of grass roots.

	Conductivity (cm/hr) at 20°C	
	At saturation	At 30cm tension
Control	7·1	0·026
After root growth	0·7	0·005
After root decay	4—10	0·007
l.s.d. (P. 0·05)	1·9	0·010

Most of the root channels left empty after decay were too wide to contain water at 30cm. tension.

6. Investigations in Crop Physiology.

(a) Dr. J. N. Black has continued his studies on the growth of subterranean clover, with emphasis on the significance of seed size and leaf area.

Three strains of subterranean clover (Bacchus Marsh, Clare and Mount Barker) were grown in pot culture. Dry weight at any one time in the early vegetative stage was linearly related to embryo weight but was independent of strain. Differences in the early growth under uniform environmental conditions are thus the result not of differing relative growth rates but of differences in seed size distribution within the population. Clare contains a higher proportion of large seed and thus as a strain would be expected to give greater early production. Leaf area per plant was also linearly related to embryo weight but was independent of strain.

A study was made of the growth of the Bacchus Marsh strain under spaced plant and sward conditions. Under conditions of spacing (25 square links per plant), plants from three widely separated seed sizes gave dry weights proportional to seed weight over almost the entire growing period. When grown in swards (25 plants per square link) dry weight was proportional to seed weight in the early part of the season but when a leaf area index of about 4 was achieved, a reduction in growth rate occurred. This leaf area was attained successively in swards from seed of large, medium and small seed, so that at the final sampling there was no significant differences between the dry weights of the swards.

Plants from small and large seed respectively were sown in swards in pure culture and in mixture, and on five occasions were harvested in layers two cm. deep. Counts of the plants showed a drop of 30% in numbers; the death of plants in the mixed sward was solely of those from small seed. Studies of the vertical leaf profile and light profile showed that leaves are not retained in the canopy at heights below that at which light extinction occurs. The importance of the position of the leaves in the canopy is illustrated by the fact that when the small-seeded plants had 25% of the leaf area of the mixed sward, they were so located as to absorb only 10% of the incident light energy.

(b) Mr. H. S. Hawkins has studied the competitive relationship between wheat and *Emex Australis* (three-cornered jack). Weeds were removed on four occasions during growth and three levels of nitrogen were applied at seeding. Weed infested crops gave a greater response to nitrogen than weed-free crops, indicating competition for nitrogen. Even at high levels of nitrogen, when this element was apparently no longer a limiting factor to growth, the yield of the weed free crop substantially exceeded that of the weedy crop, indicating competition for some other factor. It was thought that this was competition for soil moisture towards the end of the season.

(c) In a study by Mr. W. R. Stern of the light penetration into pasture swards, four nitrogen treatments were imposed on an initially uniform grass-clover sward of high density consisting of *L.rigidum* and *T.subterraneum.* This gave, at the end of the season, an almost pure clover sward at one extreme and an almost pure grass sward at the other. In the clover dominant swards 80% of the incident light was absorbed at a Leaf Area Index of approximately 3; in the grass dominant swards, the clover was almost completely shaded within two months of emergence by a similar L.A.I. of grass lying above it. In the clover dominant swards, leaves were concentrated in a narrow band giving an abrupt reduction in light values within the pasture profile; the vertical distribution of grass leaves was more diffuse for an equivalent L.A.I. in the grass dominant swards, giving a more gradual interception of the light.

(d) The emergence of seedlings is influenced both by oxygen supply and by mechanical impedance. The effect of each of these factors on the elongation of primary shoots is being studied by Mr. R. H. Sedgley. So far it has been found that the application of a pressure of 0·7 atm to the tip of shoots of *Zea mays* has little influence on the rate of elongation providing a high concentration of oxygen is maintained in the soil atmosphere. The rate of elongation of unloaded shoots decreased when the oxygen concentration fell below 10 per cent. Shoots grown for five days in an atmosphere containing one per cent oxygen were only one tenth as long as shoots grown in an atmosphere containing 20 per cent. oxygen.

(e) An apparatus involving a new principle for the measurement of the area of leaves has been developed by Mr. H. V. Jenkins. Formerly, the standard method has been to blueprint the leaves and then to measure the area with a planimeter; the blueprint method, though accurate, is very slow. The new apparatus consists of a perforated plate (600 holes per square inch) mounted on an airtight drum which is connected to a constant speed suction pump. Leaves are sucked on to the perforated plate and the pressure within the drum increases in proportion to the area of leaves. Measurement of the pressure change gives a direct measurement of leaf area. Refinements of design are continuing; meanwhile it is evident that this method, as well as being several-fold faster than blueprinting, is just as accurate. This equipment permits leaf area measurements as a component of the data of a wide range of field and pot culture experiments.

7. Pasture Management and Plant Growth.

During the 1957 growing season Mr. H. V. Jenkins studied the relationship of leaf area to the growth of pastures under several management treatments. These were grazing at 6 and 12 sheep per acre, each combined with three times of entry (4, 8 and 12 weeks) on to the pasture after the "break of season". Owing to the limited area of pastures available plot size was reduced to 0·1 acres and the area was grazed one day in 28. During autumn and winter it was found that all plots were grazed down to a common level, thus eliminating the time of entry treatments. Under the conditions of this experiment it was found that there is a relationship between the feed available per sheep and the feed consumed per sheep; thus when feed is in short supply during autumn and winter, sheep at the higher stocking rate consumed half the amount of feed per animal as did the sheep at the lower stocking rate.

No conclusive results were obtained for the effect of leaf area on the growth of pastures generally, but some evidence was obtained for the *Trifolium subterraneum* and *Oxalis pes caprae* fractions of the pasture. For these species a maximum rate of growth was obtained when the leaf area index of the pasture was approximately 4. Total dry matter yield was greatest for the heavy stocking rate and lowest for the ungrazed pasture.

8. Botany, Plant Introduction and Plant Testing.

(a) *Botany.*—During 1956 the position of Botanist was vacant and the Herbarium was maintained by an assistant; work was resumed in 1957 by Mr. D. E. Symon on his return from study leave.

The routine work of the Botanist involves the identification of plants, the maintenance of a reference herbarium and attention to the arboretum. During 1956-57, 69 reports were issued on 700 specimens for the public, other Departments and Institutions. Many of the plants were from the far north-west of this State and included the following new records for South Australia: *Cassia glutinosa, Calythrix longiflora, Rulingia loxophylla, Grevillea eriostachya, Keren draunia integrifolia, Newcastlia cladotricha,* and a species of *Corchorus.* Other new native plants were *Dampiera incana* from near Kimba and *Aristida pruinosa* from north of Lake Eyre. New weeds included *Alternanthera pungens* (Khaki Weed) from Kadina and *Amaranthus angustifolius* and *Datura ferox* from Adelaide suburbs.

The Herbarium has been maintained and the incorporation of most of the Albert Morris Herbarium donated earlier has almost doubled its size so that it now contains 18,500 specimens of which 5,400 were incorporated in the last two years. Work continues on identifying, mounting and incorporating the collections made by F. M. Hilton on Eyre Peninsula and the Flinders Ranges and of other specimens accumulated over the years.

Whilst overseas the Botanist was able to photograph many type specimens and historical collections of Cassia. These photographs have been mounted and annotated and are now available on loan to interested Botanists. However it has not yet been possible to proceed further with a revision of the genus.

At the end of 1957 a census was made of the trees in the arboretum. There are now 1,300 trees of 650 species not including a collection of Mallee type Eucalypts which now approaches 60 species. In the winter of 1957 a number of dead, dying and duplicate trees were removed to give some much needed space. The flowering gum "Urrbrae Gem" a distinctive seedling from *Euc. erythronema* selected by the head gardener, Mr. F. Couzens, has been released. It has bright reddish pink filaments tipped by yellow anthers and has flowered regularly and heavily. Altogether some 4-500 packets of seed have now been distributed. Other tree seeds have been supplied to the South Australian Housing Trust, Woods and Forests Department, Botanic Garden, and to private nurseries. Seed exchanges were made with California and South Africa to increase our tree collection from areas with a comparable climate.

Two hundred introductions of herbage plants were grown in 1957; of these more than half were grain legumes including *Vicia faba* (45 samples), *Vicia ervilia* (19) other *Vicia* spp. (12), Lentils (12), Peas (16) and *Lathyrus* spp. (13). Most of these were collected in the Mediterranean region by Mr. D. E. Symon in 1956.

New introductions have been grown in rows for observation and seed increases.

Many of the *V. faba* and *Lath. Sativus* yielded well enough to justify carrying on to further trials. The pattern of maturity for these cultivated plants collected from the Mediterranean closely follows that of the wild species already brought to Australia. Almost invariably plants from Crete were the first to flower followed by those of southern mainland Greece, northern Greece and Yugoslavia in that order.

Fewer grasses and pasture legumes were grown and none of the 1957 planting appeared to be outstanding though a Mediterranean *Phleum* has persisted well, and will provide an interesting comparison with the *Dactylis* and *Lolium* from similar areas.

(b) *Studies on Introduced Perennial Grasses.*—Work is continuing on the development of additional perennial grasses for the mild wet winter conditions and the hot dry summers of much of southern Australia.

Dactylis glomerata.—In 1956 a field trial was commenced by Mr. J. H. Silsbury to compare the growth characteristics of five distinctive lines of cocksfoot of Mediterranean origin and of one Aberystwyth bred strain. Single plants were spaced two feet apart each way, so that competition was nil or slight; forty-eight plants of each line were cut for yield of dry matter at each harvest. Harvests were

commenced in the 1956 season and will be completed in May, 1958. The experiment has been conducted under three moisture regimes:

(i) Waite Institute dry land, approx. 24 ins. annual rainfall, dry summers.
(ii) Waite Institute irrigated.
(iii) Jamestown, a country centre, approx. 17 in. rainfall.

The data obtained will provide information on comparative yield, the seasonal distribution of production, dormancy pattern during the summer and the reaction to summer irrigation of the six lines.

The studies of the phenology of the Mediterannean lines of cocksfoot, both in the foregoing experiment and in small swards, has led to the recognition of five principal types, differing in earliness, size of plant, habit and summer dormancy pattern. Each of these types has been built from selected plants within various introductions and in 1957 a block of 900 clonally established plants of each of the 5 types was planted under isolation. Yields of seed in 1957 were low but were sufficient to establish a sward trial at the Institute. Greater yields of seed are expected in 1958.

Lolium perenne.—Fifty lines of perennial ryegrass collected by the C.S.I.R.O. in the Mediterranean area were grown as spaced plants in the field during 1956-57. Several Australian ecotypes and bred varieties such as those of New Zealand and Aberystwyth were also included. Phenological studies have shown that much of the Mediterranean material is earlier in heading than the earliest of the Australian strains, is at least as productive and appears to have greater potential drought resistance. To examine this latter character more closely, clones of the ten most productive plants of each of thirty lines were planted six inches apart in plots to make small swards. These are to be sampled during 1958 to determine summer survival under competition, growth characteristics and yield.

The anatomy of the regrowth of perennial ryegrass after summer drought is being examined to compare the Mediterranean introductions with Australian and Aberystwyth lines.

(c) *Grain Legumes.*—Yield determinations of introduced species and strains of crop legumes have been continued by Messrs. J. H. Silsbury and R. W. Mallen during 1956 and 1957. *Lathyrus sativus* and *Lathyrus cicera* have been the most productive species for grain, consistently outyielding field peas by as much as 30%. In 1957 the best yielding strains of several species were also compared for seasonal forage production and recovery after early spring grazing. *Lathyrus cicera* and *Vicia sativa* proved very palatable to sheep and also showed good recovery, so that the final yield of grain was only slightly reduced below the ungrazed plots. All species produced similar amounts (approx. 6,000 lb./acre) of total dry matter in the season, except *Vicia sativa* (4,000 lb./acre). The highest grain yield of 2,680 lb./acre was obtained from *Lathyrus cicera.*

No new lines of *Pisum sativum* have yielded as well as the *Lathyrus* species but at least six may be regarded as superior (10-25%) to White Brunswick, the standard variety of field pea sown at the Waite Institute. Since the earliest of these strains flowers at least a fortnight later than White Brunswick it is proposed that a representative range of maturity types be tested under the more severe conditions of a region with shorter growing season than the Institute. Attention is also being given to the marketing qualities of the new strains which

are influenced by the suitability of the grain both for the whole and the split-pea trade. The possibility of combining the high yield of the new varieties with the earliness and seed characteristics of White Brunswick is being examined.

9. Field Nutrition of Sheep.

Field studies designed to assess the effects of nutritional stress to which young merino sheep may be subjected each year on pastures in a Mediterranean-type environment, and to define the nature of these dietary deficiencies in terms of protein and of energy have been in progress since 1954. Bodyweight changes, wool production and skeletal growth are used as the criteria of current and residual effects of different nutritional regimes imposed upon the young sheep during periods of summer drought.

The results of the first of these experiments showed that the feeding of supplements to young sheep during the first summer, or the first and second summers of life conferred a large advantage over their unsupplemented mates in terms of bodyweight gain and wool production. However for bodyweight the residual effect of such an advantage was of short duration, and for wool production no residual effect was observed on any occasion.

These studies demonstrated the capacity of average to well grown wether weaner sheep to survive relatively long periods of nutritional stress, and, when pasture feed became favourable for growth, to recover rapidly the bodyweight lost due to defective summer nutrition. Groups have lost up to 30% of their initial bodyweight in times of summer drought, but in no experiment has any sheep died from inanition or from disease secondary to starvation. On the contrary within 12 months of the cessation of summer drought conditions any benefit in bodyweight gain or frame development which accrued to sheep as a result of improved summer nutrition was no longer significant.

Since it is considered probable that the lambs most likely to succumb to malnutrition in periods of summer drought will be found in the "tail" of the flock, i.e. those lambs which have grown slowly in the pre-weaning period, Mr. W. G. Allden has commenced a further study to examine the relative effects on productivity of pre-weaning and post-weaning nutrition during the first year of life in autumn-dropped lambs.

In this experiment one group of lambs will be raised from birth to twelve months of age in such a way as to ensure that during this period growth receives no major check. Three other groups will be subjected to nutritional stress either in the pre-weaning period (0-6 months) or the post-weaning period (7-12 months), or throughout the whole 12 months' period. The study has progressed to the weaning stage, and considerable bodyweight differences are apparent between the groups.

In a further field of study, designed to assess the relative roles of available energy and protein when fed as supplements to young sheep grazing mature summer herbage, sixteen groups of sheep were fed supplements of cereal grain origin which differed in respect of energy and of protein content, according to the treatment prescribed. The experiment was of factorial design, and an individual feeding technique was adopted. From the results, which provided quantitative data for both bodyweight and wool production the mature herbage of pastures of *Phalaris tuberosa,* a subterranean clover and annual grasses was

shown to be deficient in both energy and protein for bodyweight gain, but once a small need for protein was satisfied available energy appeared to be the principal limiting factor. In terms of wool production the results showed summer pasture to be deficient in both energy and protein, the former constituent making a notable contribution in influencing wool growth.

10. Plant Breeding and Crop Genetics.

The work on cereals and on perennial grasses has been expanded in the past two years. Studies of agronomic and physiological characters, multiplication of seed and field testing parent varieties have occupied much time, together with further genetic and plant breeding studies.

(a) *Cereals.*

1. *Barley.* Work with barley is now being sponsored by the Barley Improvement Trust Fund. The initial testing by Dr. K. W. Finlay of a collection of about 800 barley varieties for a wide range of agronomic and physiological characteristics is almost complete and already many crosses have been made to produce hybrid material for further research. Most important amongst these are the 90 first generation hybrid populations produced by crossing together in all combinations ten selected parent varieties. These plants should help to elucidate the mode of inheritance of some of the quality factors in barley. Information gained from field and laboratory testing of the 800 barley varieties is being placed on a punch card filing system to enable statistical studies.

Many tests have been made to study the inter-relationship of variety, grain nitrogen content and the germination process; this work is preliminary to a study of malting behaviour in relation to these characters.

Dr. Finlay has found the percentage of nitrogen in the grain of different barley varieties to vary widely, far more so than had previously been reported. Changes in soil nitrogen also affect the grain nitrogen percentage of different varieties to a varying degree, i.e. where the grain nitrogen percentage of one variety will rise appreciably with increased soil nitrogen, that of another variety will remain relatively unaltered. The inheritance of this characteristic is of considerable importance in any programme on barley malting quality.

2. *Wheat.* A large new collection of wheat varieties from a wide range of world centres is also being studied by Dr. Finlay to enable a selection of varieties best suited for research along the following lines:

(i) Many quality factors, particularly those associated with protein are to be studied in genetic experiments, in order to elucidate their mode of inheritance and study the changes in expression of these characteristics caused by different environments. This study is in a preliminary stage of development, with principal emphasis to date on the assessment of agronomic characters.

(ii) Since the time of Farrer, Australian wheats have been intercrossed continually and only a small number of genes from outside the 'Australian' gene-pool have been introduced—mainly for disease resistance. A programme has been commenced to study the effect on yield caused by crossing in completely new gene material from overseas. This study has particular significance in view of the necessity to introduce new parent material to upgrade some of the quality factors.

(b) *Perennial Grasses.*

1. *Dactylis glomerata.*—The breeding programme being carried out by Mr. R. Knight, which aims at producing strains of *Dactylis glomerata* (cocksfoot)

suitable for cultivation as a perennial pasture grass in different agricultural areas of South Australia has continued.

Nine contrasting plants derived from the Mediterranean basin and from northern Europe have been clonally propagated and established as spaced plants and in swards. These plants have been sampled on four occasions during 1957 to obtain cumulative growth curves. Attempts have been made to correlate regrowth in the autumn of 1958 with the previous years' performance. Chemical analyses have been made of the carbohydrate reserves of a number of Dactylis strains in order to assess their relevance to the plants' summer dormancy and to regeneration performance.

The nine original plants were also hybridized in all combinations and the hybrid progenies grown during the year. These progenies are being assessed for productivity, summer dormancy and other agronomic characters.

2. *Cytology.* A cytological study is being conducted by Dr. K. Abele with the hybrid progenies of *Dactylis* mentioned above, and their parent strains to obtain evidence of subspeciation.

Material was collected from the plants in 1957 and meiosis studied. Counts are being made on quadrivalent and bivalent frequency and on chiasmata formation.

3. *Inbreeding of Phalaris.* The stocks of inbred *Phalaris tuberosa* have been maintained and some comparative trials will be established this autumn by Mr. D. E. Symon.

4. *Incompatability in Dactylis.* Three diploid plants from Israel and three plants of *Dactylis aschersoniana* have been crossed in all combinations by Mr. R. Knight to provide material for an incompatability study. Pollination and staining techniques have been developed and the incompatability within the hybrid families will be determined as soon as the plants flower this spring.

Agricultural Chemistry

During the period under review the staff of this Department has been re-organised and augmented.

Basic research on the chemistry of plant viruses and investigations on the fertility of soil have been continued, and new projects have been started in the field of general biochemistry, especially in enzymology and protein chemistry. Since the chemistry of life processes and of soil-plant-animal inter-relationships underlies the whole of agriculture, and since basic knowledge of the processes involved is still far from complete, a major aim of this Department is to strengthen the basic research and so augment the pool of fundamental knowledge on which economic applications always depend.

1. The Chemistry of Cell Growth.

The growth of all plant and animal cells is determined by a number of integrated reactions in which enzymes and co-enzymes play an essential part.

(a) *Synthesis of Co-enzyme I (Diphosphopyridine nucleotide).*

(Prof. R. K. Morton, Dr. M. R. Atkinson)

This co-enzyme, essential for the growth of all plant and animal cells, is being studied, as also are inhibitors of the enzymic synthesis, in order to obtain selective control of growth.

A technique has been developed for isolating cell nuclei in large amounts from pig liver shortly after slaughter of the animal. The enzyme, which is localized in the nucleus has been extracted and purified. Highly active preparations have been made by using conventional methods of protein separation and further work is being done to obtain the enzyme in a homogeneous condition.

Spectrophotometric assay techniques have been developed for measuring the following reactions (in both directions):

nicotinamide mononucleotide	+	adenosine triphosphate	⇄	nicotinamide adenine dinucleotide (DPN)	+	inorganic pyrophosphate

Because inhibitors may combine at one or more sites of the enzyme surface it will be necessary to study the influence of selected compounds on the reaction in both directions. A range of pyridine derivatives has been collected for study as potential inhibitors. Nicotinamide itself (in high concentrations) has been found to be an inhibitor of the forward reaction.

(b) *Comparative Studies of Tumours and Normal Tissues.*

(Prof. R. K. Morton, Dr. M. R. Atkinson and Miss E. Johnson)

Studies in which the metabolism of tumour tissue is compared with that of normal tissues were begun elsewhere and are now being continued in this Department. Studies reported elsewhere have shown that the activity of an enzyme catalysing synthesis of co-enzyme I (diphosphopyridine nucleotide, DPN) is considerably depressed in tumours of the mammary gland, and in ascites tumours, in mice. The activity of the enzyme (DPN-

pyrophosphorylase) has been determined in hepatomas induced by prolonged feeding of amino-azotoluene to strain A mice. The activity of the hepatoma was about 20 per cent. of that of the normal liver tissue in the same mice. The normal liver of the host animal did not differ from that of the liver of non-tumour-bearing mice. The activity of DPN-pyrophosphorylase of the nuclei from liver increases with age from embryonic to adult mice. It has been found that the increase is considerably greater than that to be expected from the increase in size of the nuclei which occurs during the same period.

(c) *Chemistry of Cytochromes.*

(Prof. R. K. Morton, Mr. J. McD. Armstrong)

Cystochrome b_2 crystallised by Appleby and Morton is a unique enzyme (lactic dehydrogenase of yeast) and contains both a flavin and a haem prosthetic group. Quantities of the crystalline protein have been prepared preparatory to investigations on the substrate specificity and kinetics of dehydrogenation, as well as the mechanism of the enzyme action.

Cytochrome *c* has been isolated from yeast by a method which avoids protein-denaturing agents. Dried yeast was extracted with *n*-butanol to remove lipids, and then with *buffered* sodium lactate to remove cytochrome b_2. The residue was set aside at 0° for 48 hours. Cytochrome *c* in the supernatant fluid was purified on the resin IRC 5°. Preliminary studies suggest that cytochrome *c* prepared by this method differs somewhat from that obtained by methods involving use of protein denaturants.

2. Physico-Chemical Studies of Proteins of Wheat Grain.

(Prof. R. K. Morton, Dr. J. H. Coates)

In order to study the relationship between the nature of wheat proteins and the quality of the wheat for bread-making, studies of the properties of individual proteins of the grain, and of protein-protein interaction, have been initiated. For these purposes an analytical ultra-centrifuge and a moving-boundary electrophoresis unit have been installed. Methods of extracting proteins from the wheat grain are being studied.

3. The Chemistry of Plant Viruses.

Plant viruses of economic importance appear to be increasing in respect to their number and the extent of their spread. Control measures available continue to be relatively ineffective, largely because of the absence of a sufficient body of fundamental knowledge on which to base control measures. For these reasons, and because earlier work on viruses in this Department has thrown some light on the chemistry of life processes, the work on viruses continues to be concentrated on fundamental investigations of the nature, properties, and development of plant viruses. Particular attention has been given to further study of the genetics of virus particles.

(a) *Genetics of Plant Viruses.*

(Dr. R. J. Best)

The process of recombination between strains of a plant virus, first demonstrated in these laboratories, was followed up. The table below illustrates the transfer of determinants between parent strains A and E of tomato spotted wilt (TSW) virus and the relationship between parent strains

and progeny strains "New B" and Etch isolated from plants mixedly infected by the parent strains. The symbols represent diagnostic characters on the three hosts.

Strain	Lycopersicon esculentum					Nicotiana glutinosa					Nicotiana tabacum		
		Systemic				Primary		Systemic			Primary		Systemic
	Primary NlP	Sy	Na	NlP	E	Nl	Yb	Sy	C	NlP	Nl	R	Sy
A.	+	+	+	+	−	+	−	−	0	0	+	−	−
E.	−	+	−	−	−	−	+	+	+	−	+	(+)	+
New B. . .	−	+	−	+	−	+	−	+	−	+	+	−	+
Etch. . . .	−	+	−	−	+	+	−	+	−	+	+	(+)	+

Nl = leaf necrosis, Na = apical necrosis, P = pigmentation, E = etch
Sy = systemic invasion, Yb = yellow blotch, C = chlorosis, (R) = ringspot at high temps.

The interaction between parent and recombinant strains of TSW virus has also been investigated by means of yield trials. One of the recombinants, Etch, was inoculated on to tomato plants along with each of its parents in separate experiments with the following results (yields are expressed in grammes fresh weight per plant):

Strains *inoculated*	Yield (*g. per plant*)	Strains *inoculated*	Yield (*g. per plant*)
control	64	control	53
A	13	E	41
Etch	42	Etch	33
A + Etch	33	E + Etch	40

In the course of the work, a strain was isolated which produced only non-necrotic, chlorotic, disk-shaped spots on leaves of systemically invaded tomato plants. This is direct experimental evidence in support of a conclusion drawn previously that a "yellowing" factor as such existed in the virus but is complicated in its expression by the presence of other factors in the strains so far examined. Whether the factor consists of a single determinant or of a particular arrangement of several will be tested in our chemical approach to the problem.

(b) *Nature and Properties of Virus Particles.*

(i) *Tomato Spotted Wilt (TSW) Virus.*

(Dr. R. J. Best)

Under ordinary conditions, *in vitro*, the virus of TSW loses its infectivity within a few hours. This makes it difficult to prepare samples of the virus of the purity needed to study the chemistry of the particles and their genetics at the chemical level, but attempts are being made to overcome these difficulties.

From studies of the behaviour of the virus in the ultracentrifuge and during ultra-filtration, supported by measurements of absorption of ultra-violet light, it is concluded that the virus readily forms aggregates, with consequent lowering of infectivity. The protein:nucleic acid ratio differs in different preparations. This may be due, in part at least, to a separation

of the nucleic acid and protein under the conditions of the experiments. The effect of pH, and of electrolytes and non-electrolytes, has been studied in relation to this problem.

Preliminary studies with the electron microscope have been undertaken in collaboration with Dr. Tomlin of the Department of Physics, and these support, as far as they go, the conclusions stated above in relation to aggregation and deformation of the virus particles under our experimental conditions. The diameter of apparently undeformed spherical particles is about 80mμ.

(ii) *Potato X Virus and Tobacco Mosaic Virus (TMV).*
(Dr. R. J. Best)

Stocks of pure samples of our WRS strain of potato X virus and of the "Pungent pepper" strain of tobacco mosaic virus, have been worked up as starting material for investigations on genetic transfer in these viruses.

(c) *Biological Purification, and Storage of Viruses.*
(Dr. R. J. Best, Mr. H. P. C. Gallus)

The biological purification of some of the new recombinant strains of TSW virus has been effected by the limit dilution technique as a preliminary to their further study. Strains "Etch", "Yb", and "New B" have been satisfactorily separated in this way.

Outside the plant, the normal life of the virus of TSW is less than 24 hours. Unless this can be lengthened considerably so that single-lesion isolates and stocks of recombinants can be kept in an infective state for subsequent experiments, the genetic work cannot proceed. Experimental work designed to develop techniques to meet this need has, therefore, been continued. The virus has been maintained in an infective state with little, if any, loss of infectivity for periods of up to 3·6 years by storing infective tissue in sealed containers at the temperature of solid carbon dioxide (—69°C).

(d) *Metabolism of Virus Infected and Healthy Plants.*
(Dr. R. J. Best, Mr. H. P. C. Gallus)

Investigations on the nitrogen and phosphorus metabolism of plants infected with viruses have been followed up by investigating the effect of virus infection on the *sulphur* metabolism of plants. Tomato plants were infected with TSW virus and tobacco plants with tobacco mosaic virus (TMV). Total- and protein-sulphur were determined at various times after infection and the results compared with corresponding analyses of healthy control plants.

In the case of TSW virus in tomato plants the percentage of protein-S in healthy leaves fell slightly during the course of the experiment (i.e. with age of plant) but there was a greater fall in that of the virus-infected leaves. The protein-S constituted about 27 per cent. of the total-S for both healthy and infected plants throughout the experiment. The ratio of protein-S was constant at about 18 for both healthy and infected plants, but the ratio of protein-S to protein-P increased with time in healthy plants while it decreased in virus-infected ones.

With tobacco mosaic virus in tobacco leaves the ratio of protein-N to protein-S and the ratio of protein-S to protein-P were qualitatively similar to what was found with TSW virus in tomato plants.

(e) *The Study of Fluorescent Substances Present in Plants.*

(Dr. R. J. Best, Mr. I. Napier)

The yellow-fluorescent substance of low R_F value to aqueous solvents mentioned in the previous report as a constituent of leaf-tissue of healthy and virus-infected tobacco plants has been separated from paper chromatograms and partially purified as a step towards building up enough of it to investigate its structure and properties.

4. The Chemistry and Physics of Soils and Clays.

(a) *Soil Fertility.*

(i) *Determination of Available Phosphorus in Soils.*

(Dr. C. S. Piper, Mr. D. G. Lewis)

Investigations were continued on the value of borate buffers containing a chelating agent as a means of measuring available phosphorus in the soil. These showed that the best extractant was a borate buffer at pH 9·0 containing 0·5 per cent. of di-sodium versenate. Using this extractant on a large number of soils an attempt was made to correlate the P extracted with known phosphate responses. In the case of some pot experiments with soils that had received phosphate, highly significant correlations were obtained between the phosphate extracted and the yield of dry matter and also with the phosphorus uptake by the plant. In field trials on one soil type highly significant correlations were obtained between phosphate extracted by the buffer and the total amount of superphosphate that had been applied to the soil, irrespective of the kind of crop grown.

(ii) *The Potassium Status of Seddon Soils.*

(Dr. C. S. Piper, Mr. D. G. Lewis)

Analyses of plant samples from the previous four years showed that the K content of the dry matter had decreased progressively during that period in all cases. The level of exchangeable K was found to be uniformly low in all pots (at 0·07 milli-equivalents per 100 grammes).

After a basal phosphate dressing equivalent to 3 cwt. superphosphate per acre and an application of 2 cwt. of potassium sulphate per acre to the K treated pots, definite growth responses were obtained in the fifth crop of subterranean clover; the six control pots yielded only 30-40 per cent. as much dry matter as the six K treated pots.

(iii) *Nutrient Uptake by Wheat Plants in Relation to Soil Properties.*

(Dr. J. P. Quirk, Mr. D. G. Lewis)

This project is designed to study the release of ions from adsorption sites on the solid phase to the soil solution, movement through the soil solution, and uptake by plants. The initial part of the work has been concerned with the time-rate of uptake characteristic of wheat plants (Warigo) grown under controlled environmental conditions. The main nutrient under investigation is P but attention is also being given to the accumulation by the plant of N and K.

The results indicate that after an initial lag the uptake proceeds almost linearly with time up to flowering over a wide range of soil-P conditions. Under favourable conditions the rate of uptake of P from the soil solution

was in close agreement with the uptake from culture solutions many times more concentrated. Work is proceeding to define the condition of P in the soil with reference to the degree of anion saturation and the phosphate potential of the soil solution.

(b) *The Mechanism of Clay Swelling and Clay-Water relationships.*
(Dr. J. P. Quirk, Mr. L. A. G. Aylmore)

The aims of this project are to sort out the relative contributions of pore adsorption and swelling adsorption by soils and, to study the interaction of the negatively charged plate-shaped clay particles with a view to controlling swelling.

The preliminary phase of the work has been concerned with the building up of equipment and the preparation of clay minerals saturated with sodium, potassium and calcium. The materials being investigated are representative samples of the clay minerals kaolinite, illite and montmorillonite. The surface area of these materials ranges from 12 m^2/g to 760 m^2/g.

So far the work has been mainly on Ca^{++} saturated clays. At full swelling it has been found that the film thickness varies somewhat but has a magnitude of about 30Å. To reduce this film thickness appreciably, $CaCl_2$ solutions with a concentration greater than molar are required.

(c) *The Negative Adsorption (repulsion) of Chloride Ions by Clay Surfaces.*
(Dr. J. P. Quirk)

The distribution of anions in the soil solution in the vicinity of negatively charged surfaces is of interest in relation to plant nutrition. It is also of interest in relation to Schofield's theory concerning the calculation of surface areas.

Using potassium saturated clays, very good agreement has been found between the surface areas calculated according to Schofield's theory and those determined by the conventional B.E.T. method. A kaolinite clay showed concomitant positive and negative adsorption of chloride at pH values as high as 10. The positive adsorption was a typical concentration-dependent anion adsorption and appears to be associated with the peripheral faces of kaolinite crystals.

It has been shown that for Ca^{++}-clay systems Schofield's theory breaks down. The depth from which chloride is excluded is 10Å in 0·01N $CaCl_2$ solution. This indicates a double layer development of about 20Å, a figure in reasonable agreement with results obtained from the project on clay swelling.

Information is also being obtained on the entry of chloride into intra-crystalline regions where silicate sheets are separated by two or four water layers.

5. Analytical Methods.
(Mr. A. C. Jennings)

The biuret method of determination of protein nitrogen has been investigated in order to determine the suitability of this procedure for estimating protein nitrogen in cereals. An improved biuret method has been developed for use with barley. It permits examination of large numbers of samples and is sufficiently accurate for use in most cereal breeding programmes.

Plant Physiology

During the latter part of the period under review research activities in Plant Physiology have been considerably expanded. This has followed, first the provision of funds by the Barley Improvement Trust Fund for research on physiological aspects of the barley plant, and secondly, the acceptance of teaching and research responsibilities in Horticulture. Growth-regulator and carbohydrate metabolism have continued as central themes for the Department's work while investigations on the nutrition of tobacco have been concluded.

1. Growth-Regulators.

(Dr. N. G. Marinos, Dr. L. G. Paleg)

In the previous report the high resistance of soursob (*Oxalis pes-caprae*) to weedicides of the 2,4-D type was mentioned and on the basis of work with excised leaves this tolerance was attributed to inactivation of the growth-regulator in the leaf. Later it was observed that treatment of intact plants with 2,4-D or related compounds stimulated subsequent bulb germination. The mechanisms underlying these responses are still under investigation. However, the work has emphasised the problem which is basic to the control of soursob and also many other bulbous weeds. Thus, although the above ground parts of these weeds are comparatively unaffected by many weedicides, it is the power of regeneration inherent in the below ground organs that is responsible for their success as weeds. A morphological examination of these organs thus emerges as a field of study which must precede control measures that are more soundly based than hitherto. In this connexion experiments are now in progress on dormancy of soursob bulbs, and it is already known that dissected meristems germinate about one week after this tissue has been excised and washed in running water (for 48 hours). The possibility that a growth inhibitor has been removed by this treatment is currently being explored. A further aspect of root growth receiving attention is the contraction of the tuberous root which leads to a considerable vertical distribution of the daughter bulbs. It appears that contraction of the tuberous root is under the influence of the aerial parts of the plant and further that elongation of the rhizome bearing the bulbs is dependent upon endogenous auxin. Work on these aspects is continuing.

Studies have continued on the control of soursob under field conditions, and on the basis of preliminary pot experiments with maleic hydrazide this substance is now being more widely tested. When maleic hydrazide is applied soon after the plant's emergence there is a stunting of growth and a reduction in the number of bulbs formed. However the most striking response is in the following season when bulbs from treated plants show a significant reduction in percentage germination. The percentage of non-germinating bulbs can be increased with higher concentrations of maleic hydrazide and also with applications later in the growing season. In this type of experiment 100% inhibition of germination has been achieved by spraying plants to run off with a concentration of crude maleic hydrazide (30% of active ingredient) greater than 2%. Significant reductions in germination have also been obtained with concentrations of maleic hydrazide as low as 0·2%. Although these findings still await confirma-

tion in the field it would appear that maleic hydrazide has a potential use, although it is unlikely to be selective.

A second chemical which has proved useful in preventing growth of soursob is a volatile dithiocarbamate marketed under the name of Vapam. This substance has been tested at different rates of application, growth stages of the plant, and watering rates following application. Early treatments produce an initial reduction in soursob populations although normal plants arise from bulbs that survive treatment, and by the end of the season there appears little difference between the number of bulbs produced per unit volume of soil under treated and control stands. Treatment at a later stage of growth is more effective and results in a complete absence of viable bulbs at the end of the growing season.

The range of applications of growth-regulators is continually widening and a recently discovered growth-regulator, gibberellic acid, is known to exert marked effects on the flowering behaviour of several plants. In the course of studies on barley to be referred to below the effects of gibberellic acid on early-, mid-, and late-season varieties were examined with a view to determining whether or not this substance influenced flowering behaviour. Four rates of application (0, 10, 50 and 250 μg/plant/week) were used, the solutions being freshly prepared as detergent-water sprays. Since nutritional status complicated the effects of gibberellic acid with other species, the barley was grown at two levels of nitrogen nutrition. Results indicated an extreme inhibition of growth at all concentrations with the effect being quite marked on the production of flowering heads; abortion of flowers was common and completely empty flower heads developed on many plants. In the past inhibition effects of gibberellic acid have received scant attention. It may well be that other conditions of application lead to results different from those reported here, but this finding does underline the importance of testing the newer growth-regulators under various conditions, and on many different varieties of plants, before attempting to derive any definite conclusions.

2. Responses of Barley to Drought.

(Dr. D. Aspinall)

The importance of detailed knowledge of the effects of water stress on plants has long been recognized by physiologists, but most attention in studies on cereals has been directed towards effects on vegetative growth rather than on flowering and fruiting. In the present work most emphasis is being given to drought during this later stage of growth since such treatment approximates most closely to changes in the field under Australian conditions. The variety "Prior" used in this work is a local selection and is the major variety grown in South Australia. Experiments were carried out in large glazed pots, a choice determined by the ease and precision with which the water supply could be controlled. Droughting treatments were applied to coincide with definite stages in the flowering and ripening of the plant, and the technique was to allow the soil in the pots to lose water down to the permanent wilting point and then to rewater up to field capacity. Once droughting had begun, the soil was allowed to cycle between field capacity and permanent wilting point until harvest, hence the number of droughting cycles varied with the treatment. Data were collected on both vegetative and reproductive stages of growth. In the former stage the rate of tillering was only slightly reduced by the droughting treatments and was very high as compared with field conditions. The increased tillering is attributed to

the higher fertility in the pots as compared with field conditions. The rate of production of new leaves was markedly reduced with the onset of droughting although their rate of senescence seemed little affected. The data on reproductive growth was examined to determine which component of yield (i.e. the number of tillers per plant, the percentage of these tillers which bear ears, the number of grains in each ear, and the weight of grains), was primarily affected by the droughting treatments. Of these components, grains per ear, and grain weight showed the most significant changes. On the whole the droughting treatments reduced the grain numbers in ears of comparable age, an effect which was much more pronounced on ears which flowered late. However precise comparisons cannot be drawn because the exact flowering date of these ears was not recorded. Early droughting had a striking effect on the size of grain, with the effect decreasing as droughting was delayed (29·8 mg./grain through to 45·5 mg./grain). The responses of meristematic activity to water stress as evidenced by changing leaf numbers and numbers of grain per ear are to be the subjects of further study.

3. Carbohydrate Metabolism.

(Dr. L. H. May, Dr. L. G. Paleg)

Studies on the influence of environmental factors on starch metabolism in the grain of barley have continued. The finding that the amounts of two enzymes related to starch synthesis and degradation vary with different levels of nitrogen nutrition has been fully confirmed by more detailed work and moreover the same two enzyme activities change in relation to one another during maturation of the grain. To determine whether these changes in enzyme activity are reflected in the type of starch granule formed, microscopic studies of starch deposition in barley endosperm have been undertaken. Preliminary work established the pattern of starch granule formation under normal conditions, and it appears that two types of starch granule are produced. The pattern of starch granule formation under various environments, especially different nutritional levels, is currently under examination.

A second aspect of carbohydrate accumulation in the barley grain which has come under close examination is the role of carbon dioxide fixation within the cereal ear as a factor determining the final yield. Several estimates have been made during the past few decades and these have led to the general conclusion that up to 30% of the dry weight of the grain arises from photosynthesis within the ear itself. However, the technique used in these investigations has usally been that of opaque shading wherein light is excluded from the ear from emergence through to maturation. The earlier workers drew attention to the objections against this technique and two approaches to the problem were planned in an effort to circumvent the difficulties inherent in it. In the first, three varieties of barley which produce ears differing widely in photosynthetic activity were grown to ear emergence when selected heads were covered with either opaque, or transparent, covers or left free as controls. In this way it was hopd to decide whether any reduction in yield was related to the prevention of photosynthetic activity or whether this reduction was more closely related to some other change brought about by the cover (either opaque or transparent). Results have, however, been inconclusive and all that can be claimed at present is that under our conditions the ear's contribution to yield is lower than estimated by workers elsewhere. In

the second approach radio-active carbon dioxide was passed over an enclosed barley ear while the remainder of the plant was exposed to the normal environmental conditions. In this way incorporation of Carbon-14 into the grain was traced and the experiments leave no doubt that carbon dioxide was assimilated by the ear up to at least 40 days after fertilization had occurred, and that the carbon so incorporated was permanently retained in the following forms, soluble sugar, starch, and structural carbohydrate. There is evidence also that carbon fixed within the head during the early stages after fertilization was translocated down into the stem as far as the node bearing the flag leaf. Later in the development of the ear, however, no translocation was observed. It follows that the green parts of the ear, and their ability to remain active during the later phases of ear development, are factors requiring consideration by the plant breeder when new varieties are being developed.

Two further lines of research on carbohydrate metabolism in cereal endosperm have a bearing on several aspects of the malting process, and both stem from the fact that, despite recent advances in our knowledge of carbohydrate metabolism, the factors controlling the availability of starch as substrate are still largely unknown. In the first, the reason for the very low rate of respiration in barley endosperm, a tissue amply supplied with carbohydrate, is being examined. In the past workers have attributed this to an absence of respiratory centres but our work suggests that this might not be the reason as the incubation of endosperm tissue with various non-carbohydrate respirable materials led to large increases in respiration rate. However very recent work suggests that some, and perhaps all, of the observed respiration may be due to bacterial contamination residing on or in the grain itself, and an examination of various bactericides, and respiratory substrates is now in hand in an attempt to localise the seat of induced respiration. The second inquiry has arisen through reports of a stimulation by the plant growth-regulator, gibberellic acid, of beta-amylase activity and seed germination. The aim is to elucidate the mechanism of stimulation of beta-amylase. When barley endosperm is placed in water for several hours beta-amylase activity appears in the surrounding medium, and we have confirmed that the addition of gibberellic acid to the medium, prior to soaking the endosperm, increases this enzymic activity. However, addition of gibberellic acid to the medium following the soaking period produces no effect. Thus it is likely that gibberellic acid is hastening some process such as diffusion rather than directly influencing the enzyme's activity. Detailed work on this project is still in progress.

4. Grain Storage.

(Dr. L. H. May)

In view of recent trends towards the bulk handling of wheat in South Australia, the Australian Barley Board established several experimental silos to define the behaviour of barley under bulk storage conditions. Work was also undertaken at the Waite Institute to examine the viability of small amounts of grain stored under a wide variety of environmental conditions throughout 18 months.

In the small scale experiments various concentrations of gases (carbon dioxide at 0·03%, 5·0% and 10·0%, and oxygen at 2·0%, 10·0% and 20·0%) were combined with three temperatures, 15°C, 25°C and 35°C in all possible combinations so that 27 treatments were applied. It appeared that the many gas

combinations had little or no effect on germination, and the only treatment which produced a response was the higher temperatures. At these higher levels the percentage germination, as well as the rate of germination, slowly fell.

At the end of 1957, when their trials were completed, the Australian Barley Board made their results available for analysis and collation with our own findings. The following data were available for samples of grain taken periodically over 9 months from silos at Port Adelaide, Owen, and Wynarka; germination capacity, germination rate index, temperature and moisture content. The moisture content was in the main uniform throughout the experimental period within the relatively narrow limits of 10·0-12·5%. However, there is reason to believe that moisture content may be a critical factor, as a large number of storage fungi were shown to be present and oversea work on wheat has shown that invasion by fungi quickly results from small increases in moisture content above a critical level. The germination capacity and rate index usually increased during the first 50 days of storage, remained uniformly high for the next 150-200 days and then fell, in some samples very dramatically. The decrease was usually, but not always, associated with an increase in temperature and was always most rapid when accompanied by an increase in moisture content. In view of results from the small scale tests it would seem unlikely that the effect of temperature, per se, on germination capacity would be other than slow, thus this effect may have been responsible for some of the moderate decreases recorded in germination percentage. However the combination of high temperatures and increasing moisture content may have provided the conditions leading to rapid invasion by fungi which could account for the catastrophic decrease in germination percentage recorded in some samples. This general pattern was followed in both country silos and also in one at Port Adelaide. Grain which was transferred to and fro between two additional silos at Port Adelaide appears at first sight to have departed from this pattern, since samples seemed to retain a high germination capacity and germination rate index for longer than grain stored continuously in the one silo at this centre. Unfortunately this finding cannot be regarded as firmly established because the trials could not be continued for the same length of time as those in which grain was stored continuously in the one silo. It should be emphasized that these findings relate to grain which was stored throughout 1957, a rather dry season, and which had a low initial moisture content. Further work to determine responses under other conditions, and to evaluate the role of changes in the moisture content of the grain, would seem an urgent need.

5. Nutrition.

(Dr. L. H. May, Mr. G. R. Edwards)

Collaborative work continued with the Commonwealth Scientific and Industrial Research Organization on changes in the carbohydrate and amino-acid components of tobacco leaves in response to nutritional treatment. In summary, it was found that low levels of potassium nutrition produced leaves with a curing behaviour similar to that observed in some of the poorer quality tobacco leaf produced by commercial growers. Although changes in sugar and amino-acid composition accompany variations in nutritional level, a close correlation between these metabolites and curing behaviour was not evident. However recent work on respiratory rates and changes in certain fluorescent components suggest that changes in phenolic substances may be closely related to abnormal curing

behaviour. Further work on these problems has now been taken over by the Tobacco Research Institute at Mareeba in Queensland.

Following the appointment of a Lecturer in Horticulture, fertiliser trials on potatoes, initiated in the Department of Agriculture, have been continued in collaboration with this organization. These trials have the aim of determining an economic fertiliser treatment for potatoes on the light podsolised sands of the South-East of South Australia. In general it has been established that responses follow nitrogen and potassium additions, although undesirable effects such as leaf rolling and plant collapse frequently follow the use of sulphate of ammonia. A pot experiment using soil from the above area was conducted to investigate the disturbed metabolism leading to nutritional leaf roll. Beyond establishing that the disorder can be reproduced in pots little progress has been made so far.

Entomology

Research activities during 1956 and 1957 were concerned principally with the following topics: (a) microanatomy and histology of the insect cuticle; (b) physiology and behaviour of aphids; (c) digestive and feeding mechanisms of plant-sucking insects; (d) taxonomy of the scale insects (Coccoidea); (e) lucerne entomology, with reference to insects affecting fodder and seed production, and pollination; (f) ecology of the codling moth, and control problems arising from its increasing resistance to DDT; (g) biology of the grape phylloxera; (h) studies of pasture insects, particularly of high-rainfall areas; (i) certain aspects of apiculture, notably the Kangaroo Island Ligurian bee; (j) biology of *Agrotis infusa* Boisd.; attention was given to a number of other problems, which may be developed further in future. These programmes are discussed in more detail below.

Advisory services in entomology were provided to State Departments, principally the Departments of Agriculture, and of Woods and Forests, and to the quarantine authorities.

1. General.

The outbreak of the locust *Chortoicetes terminifera* (Walker), which reached plague proportions over northern parts of the State in the early summer of 1955, ran a typical course; flying swarms derived from the spring generation moved in a generally southerly direction during November-December, 1955, and laid eggs as far south as Adelaide. Their numbers were considerably reduced by the control campaign maintained by the South Australian Department of Agriculture, which averted serious agricultural damage; the surviving fliers laid eggs which hatched in January, 1956. Hot rainless conditions are normal at this time, and there is no green herbage; the first-instar hoppers failed to survive, and the outbreak terminated. In the two years since that time *Chortoicetes* numbers in South Australia have remained very low.

The whitefly *Orchamus citri* (Takahashi) which has been known for many years on citrus in coastal New South Wales (and which appears to be native to north-east Australia) has spread slowly along the Murray River Valley in a westerly direction. Several years ago it appeared at Mildura; in the summer of 1956-57 it was reported for the first time from Renmark, and it is now established there and at Berri. Its economic status is not yet defined but it appears to be of limited significance.

In November, 1957, the Mediterranean fruitfly *Ceratitis capitata* (Wied.) was reported as established in home gardens at Port Augusta. This was the first recognized occurrence of this insect in South Australia since the eradication of the intense outbreak in Adelaide suburbs of 1948-50. Port Augusta lies well outside the horticultural areas of the State; it is the railhead of the trans-Australian railway to Western Australia, where *Ceratitis* is endemic. Eradication procedures were undertaken by the Department of Agriculture, which also made surveys in other northern towns without finding further infestations.

2. Investigations on Aphids.

Dr. B. Johnson has continued his studies on reproduction, form determination, and flight-muscle histolysis in aphids; the species *Aphis craccivora* Koch has been used principally. The work has dealt with the following aspects:

(a) *Studies on Reproduction and Form Determination.*

Elicitation of the parturition response in aphids by decapitation has been used as a method of studying the control of reproduction, and the time and nature of determination of alate and apterous progeny. As in some other insects which have been studied, decapitation of aphids removes a nervous inhibition of the parturition response, and embryos are then born as they reach a certain stage of development. Only apterous progeny are produced, and this suggests that some stimulus from the head of the parent is normally necessary before birth for the determination of alate forms. An attempt to ascertain the nature of this stimulus is being made.

(b) *Studies on the Effects of Parasitization.*

Parasitization of aphids by a braconid wasp has been shown to cause interference with the normal physiological control of development of the host. At different stages of its growth the parasite has opposite influences on the host; in the larval stages it facilitates the formation of adult structures, whereas in the egg stage it has a "juvenilizing" effect. When winged nymphs are parasitized, this leads to the suppression of alate (truly adult) structures and thus the production of intermediates between alatae and apterae. Parasitization causes a number of changes in the internal organs of aphids, especially the fat-body and reproductive organs, and a histological study of this is being undertaken.

(c) *Study of Muscle Histolysis in alate aphids.*

A histological study of the degeneration of the flight muscles of alate aphids has been made and several features of muscle autolysis which have not previously been recorded were observed. The fibrils of the muscles appear to break down independently of one another, each becoming converted at different points along its length to material soluble in the haemolymph; there is no phagocytosis accompanying histolysis. The muscle nuclei persist for a considerable time after the fibrils have disappeared. The sarcolemma, the tracheal system ventilating the muscles, and the tonofibrillae do not break down at all. Concurrently with muscle breakdown there is heightened activity in the fat body and the cells become hypertrophied and accumulate large quantities of fat.

3. Studies on the Insect Cuticle.

The histology and chemistry of the insect integument have been further studied by Mr. H. F. Lower. His work covered the following topics:

(a) The integumentary changes occuring in the course of development of the noctuid moth *Persectania ewingii* (Wwd.) from larva to adult have been investigated. During moulting in this species, the ecdysial membrane has been shown to form a primary cuticle secreted by the hypodermis as its first activity after its retraction from the old cuticle. Further information on the peculiar nature and mode of formation of the pupal cuticle has been obtained.

(b) The chemical composition of the test of the endemic lac insect, *Austrotachardia acaciae* Maskell has been elucidated. In addition to a lac, a wax, and

a dye, peculiar lac-like substances differing chemically and physically from true lacs, are also present. Chitin is a minor constituent only of the test.

(c) A study has been made of the integument of the highly-specialized, deserticolous mealy bug, *Epicoccus* sp. The very thick cuticle appears to function as a reserve storage-organ during times of stress.

(d) Work done on the cuticle of the soil-living larva, pre-pupa, and pupa of the scarab *Aphodius howitti* Hope shows the cuticles of the two former stages to be normally much abraded. When the insect pupates, although its epicuticle is intact, resistance to water-loss increases threefold only. The pupal cuticle is the thinnest of any stage in the life cycle. In this species, the epicuticle appears to play a minor part only in conservation of water.

4. The Pasture Cockchafer.

Dr. D. A. Maelzer completed a comprehensive study of the ecology of the pasture cockchafer *Aphodius howitti* Hope, which had been in progress during the past four years. The work, some details of which were given in a previous report, has provided a clear picture of the biology of the insect and has indicated the factors which are conducive to the production of plagues in particular years.

A. howitti is a native insect which occurs widely in the State, but the investigation was restricted to the lower South East, where the species is an established pest of improved pastures, and periodically causes widespread damage. The adult beetles are present in December-January, but lie quiescent in the soil until stimulated to emerge by rain. It was shown that moisture in the soil influences the survival-rate of adults and the number of eggs laid by females after emerging from their prepupal cells. Rainfall during the possible flight period is considered to have a marked effect on the birth-rate of the species.

The eggs are laid and hatch in the soil during February-March. The 1st instar larvae seem, however, to remain in the soil until it is saturated with rain. It was observed that the young larvae do not feed much before migrating to the surface of the soil, and, since this migration usually coincides with the "break" of the season they are sometimes exposed to drought when the season breaks late. If the drought is prolonged many may die of starvation.

The young larvae, once at the surface, construct tunnels in the soil and at first feed mainly on organic matter and plant or animal debris. Later they enlarge their tunnels and eat living plant material. It was shown that young larvae develop slowly and die in large numbers in native, unimproved pastures which contain relatively little organic matter. The 2nd and 3rd instar larvae face a further hazard in winter when excess water may cause large numbers to drown or may promote a high infection rate with the fungus *Cordyceps aphodii* Mathieson.

It was concluded that food is a major factor influencing the distribution and abundance of *A. howitti* in the area studied, but that even when food was not limiting, numbers fluctuated from year to year. Parasites, apart from *Cordyceps*, were observed to have little effect on the populations of *A. howitti*; the fluctuations in numbers seemed to be determined by the weather. Estimates of the wetness of the summer period, the duration of drought affecting the 1st instar larvae, and the wetness of winter were used to assess the effects of weather, in these critical periods, upon the numbers of *A. howitti* from season to season.

The behaviour of the adult beetle was studied in some detail to determine the types of places in which eggs were laid. It was found that pastures which had been mowed, which had been overgrazed, or which had consisted of a dominant stand of subterranean clover or other annual plants, offered surfaces attractive to the adult female for laying eggs. Practices which maintain a continuous cover of herbage during mid-summer will reduce considerably the extent to which pastures are selected for egg-laying. These matters will be discussed in detail in forthcoming publications.

5. Codling Moth (*Cydia pomonella* L.).

As a result of the development of DDT resistance in populations of codling moth in South Australia, an ecological study of the problem was commenced by Dr. Maelzer. In order to enable quantitative studies to be made, a method is being sought of sampling apple trees without picking the entire crop carried by each tree. A number of trees were stripped of their fruit, and the variances of samples obtained by various methods were compared with the variances to be expected from random sampling.

A light-trap and bait-traps were operated during the past summer. Flights of moths as indicated by trapping are being examined in relation to prevailing weather classified in terms of air-masses, using daily synoptic weather charts. The possibility of forecasting periods of flight by this method are being investigated. In addition, air-mass analysis is being used as a working hypothesis to examine the effects of weather on all stages of the codling moth.

The insecticides malathion and parathion are being used widely in South Australia at present to replace DDT in codling moth control. These materials lack the persistence of DDT; studies are in progress to determine the points in the life cycle of the insect at which their effects are produced, so that spray applications may be timed more accurately. Preliminary tests in the orchard with malathion applied at currently-recommended dosages showed that malathion was highly toxic to adult moths, in addition to giving high percentage mortality of 1st instar larvae.

6. Studies on Scale Insects.

Investigations upon the taxonomy of the scale insects (Coccoidea) have been continued by Miss Helen M. Brookes. A survey was made of the species occurring in South Australia and a list of naturalized species and their host plants was published.

Attention has been given to the taxonomy of the mealybugs (Pseudococcidae). The genus *Pseudococcus* in South Australia includes a group of closely-related forms belonging to the P. *malacearum-maritimus* complex; an attempt to clarify their relationships by cross-breeding methods is in progress.

A study has been undertaken of the members of the native genus *Epicoccus*, of which a number of species exist, associated with hosts of the genus *Acacia*. A review of the group is being prepared.

Observations have also been made upon the biology of two species of Aleyrodidae that have recently appeared on *Citrus* in South Australia. These are *Orchamus citri* (Takahashi), and *Bemisia giffardi* (Kotinsky).

7. Feeding and Digestion in Hemiptera.

Dr. P. W. Miles has been engaged in studies of certain aspects of the feeding processes in Hemiptera. These are as follows:

(a) *Investigation of the Stylet Mechanism in Hemiptera.*

The investigation of artificial substrates in which the stylet-action of locally-available Heteroptera could be observed and photographed showed that *Nezara viridula* L. especially, feeds readily on a sucrose-agar-gelatine film. The stylet action of this and other species will be analyzed by means of cinephotomicrography.

(b) *Chemoreception in Hemiptera.*

The exterior body surfaces (with the exception of the rostrum) were tested for contact chemoreceptors in *Dindymus versicolor* H. Sch. (Pyrrhocoridae), *Nezara viridula* L. (Pentatomidae), and *Mictis profana* Fabr. (Coreidae). In *Nezara* and *Mictis,* contact chemoreceptors were found on the fore- and mid-tarsi and on the tips of the antennae — the same distribution as previously found by him in *Oncopeltus fasciatus* Dall. (Lygaeidae) (an earlier account of contact chemoreception in *Oncopeltus* reported a different distribution, namely, on all the tarsi, but none on the antennae). *Dindymus,* although belonging to a family closely related to that of *Oncopeltus,* showed contact chemoreceptors on the tips of the antennae only (again, the rostrum itself was not tested).

Experiments on *Dindymus* and *Nezara* showed that these insects are able to discriminate between non-sapid, acceptable and unacceptable liquids into which the stylet bundle is dipped, when contact chemoreceptors on the external body surfaces—including any that may occur on the rostrum—are either masked or given conflicting stimuli. This is in agreement with previous experiments on *Oncopeltus* and confirms the suggestion that a gustatory organ exists internal to the stylet food-canal in Hemiptera.

(c) *Digestive Enzymes in Hemiptera.*

Attempts have been made to find reliable methods for the quantitative micro-estimation of pectin methylesterase and polygalacturonase and of lipase in insects. Previous tests have tended to be either crudely qualitative or of doubtful significance because of the long incubation times required.

It has been reported that some aphids secrete a salivary pectin polygalacturonase, and investigations were started to determine whether this is true in the case of *Aphis craccivora.* Two methods have been tried—viscosimetry and paper chromatography of low-methoxy-pectin solutions incubated with whole-aphid extracts. The former test is far the more sensitive and it also gives quantitative results; but the extracts contain an agent or agents (at present thought to be calcium ions) which gel the substrate. Methods of overcoming this are still under investigation.

Both tributyrin and "Tween 20" have been tried as substrates for lipase determinations. Tributyrin appears to be the more sensitive, but Tween 20 which is freely soluble would give more reliable quantitative results. The limits of sensitivity of these methods are being studied.

(d) *Plant Deformities Caused by Sucking Insects.*

Phenacantha australiae Kirk. (Lygaeidae) which occurs in lucerne was found to cause small warty growths on the stems of broad bean seedlings. Further investigation will be made to determine whether this is a true toxic effect or due to mechanical stoppage of vascular tissue.

(e) *Rearing of Laboratory Insects.*

For projects on digestion and nutrition of insects, large, easily-maintained colonies are required. After several unsuccessful trials, a method of breeding

Nezara based on a method in use in CSIRO Division of Entomology, Canberra, is now in operation. It was found that *Dindymus* lays its eggs in moist soil and that they desiccate unless kept in a saturated atmosphere. Attempts to meet these conditions on a semi-permanent basis in the laboratory have so far proved unsatisfactory, but greenhouse experiments utilizing potted plants hold more promise and are continuing. *Phenacantha* was kept successfully for some months and several generations on peas and bean pods in the laboratory.

8. Entomological Problems of Lucerne.

Mr. K. M. Doull has been engaged in a study of the entomological problems of lucerne in South Australia, with special reference to the causes of low seed production. His preliminary surveys show that the major problems are:

(i) attacks by the pink cutworm *Agrotis munda* Walk. on young lucerne in the first spring after sowing. This has been an unrecognized cause of poor establishment of lucerne in the Upper South East. The identification of this insect and the recommendation for the use of 1½ oz. p.p.i.-DDT per acre in October have transformed the establishment of lucerne in the Coonalpyn Downs area;

(ii) the cutworm *Heliothis punctigera* Wall. which attacks buds and flowers and has been the cause of a great deal of flower-fall previously thought due to lack of pollination;

(iii) the native pod-borer *Etiella behrii* (Zell.) which appears to be more severe in the sandy areas of the Coonalpyn district, although it occurs throughout the lucerne areas of the State. This insect, the caterpillar of which feeds on the seeds of lucerne, is a permanent inhabitant of the lucerne fields of the State. It has caused virtually complete destruction of some seed harvests;

(iv) the seed-wasp *Bruchophagus gibbus* (Boh.) occurs generally but is more destructive in northern seed growing areas, where up to 75 per cent. of autumn seed may be destroyed;

(v) inefficient pollination of the crop, due to virtual elimination of native pollinators as clearing of natural woodland and the expanding use of land for agriculture reduced breeding-places for these insects.

During the period experiments in control of insect pests and the planned use of honeybees have been carried out. These experiments showed that the earlier recommendations for the use of parathion to control *Etiella* were justified. The most successful chemical used has been trithion, which has a longer residual effect than parathion but lower mammalian toxicity.

Under irrigation the use of honeybees at the rate of two or more hives per acre has given spectacular increases in seed yields. The highest recorded yield has been 1,232 pounds of clean seed per acre as against a previous best yield of 400 pounds per acre. Under dry-land conditions on the sands of the Coonalpyn Downs, the use of bees at one hive to two acres, together with careful attention to spraying has raised average yields from 30 to 100 pounds per acre. The highest yield under these conditions—in a drought year—was 155 pounds. It is considered that lucerne seed yields throughout the State can be substantially increased as control methods for insect pests, and effective use of honeybees as pollinators are developed.

A detailed study was commenced by Mr. D. J. Taylor on the biology and ecology of *Etiella behrii* (Zell.), (Lepidoptera Phycitidae), the native pod-borer. The adult moths appear at the beginning of the summer and are abundant

during the months, November to February. Eggs are laid on or near the lucerne inflorescence, and on hatching, the larvae bore into the newly-formed pods and feed on the developing seeds. When fully grown the caterpillar goes down to the ground and pupates in a silken cocoon formed in the surface inch of the soil. Field and laboratory investigations are being made on the effect of various environmental factors, including climate and other host plants on the distribution and seasonal abundance of this moth.

Field studies of control methods of this insect have been undertaken by Messrs. Doull and Taylor. The currently-used measures, consisting of low-volume applications of parathion during the period of seed-setting in December and January, present a hazard to the honeybee population. Field trials have therefore been carried out to compare the relative efficiency of four other insecticides, reported to be less toxic to bees, with parathion. Trithion, dipterex, metasystox and DDT were used, on replicated plots; the results indicated that trithion, parathion and DDT gave increased yields of the order of 35 per cent., 30 per cent., and 25 per cent. over untreated plots.

9. Pasture Insects.

A study was commenced by Mr. L. D. Crawford of the biology of *Adoryphorus couloni* Burm., a dynastid beetle which occurs widely in pastures in south-eastern Australia, and which appears to be restricted in South Australia to the south-eastern corner. The larvae are known there as "curl-grubs"; they are root-feeders, and occur on podsolized sands and terra rossa soils. They are an occasional pest of semi-improved pastures; in some seasons, notably the winter of 1957, they were present in some localities in sufficient numbers to destroy considerable areas of pastures, and necessitate their replacement with cereal crops.

The life-cycle probably extends over three years. The adults fly and lay eggs in October-November, but the larvae appear to do little damage to pasture until about 18 months later when they are fully grown. The bare patches left by their activity are susceptible to attack by *Aphodius* in the following autumn. After pupation the adults remain for a further winter in the soil before emerging.

Pot cultures of perennial rye grass showed a correlation between the density of larvae and the yield and rate of growth of the plants. In contrast with wheat, which was readily attacked, oat seedlings proved resistant, even at high infestation rates.

10. Grape Phylloxera.

A study was continued by Mr. D. C. Swan of the biology of the grape phylloxera, *Dactylosphaera vitifolii* (Fitch) as it occurs in Australia. It was first recognized in Victoria in 1877, where it spread by 1900 to principal viticultural areas, and also to the Sydney district; it was found at Brisbane in 1910. Since that time it has not been found in any new locality, although vines are cultivated in all mainland States. The work reported here was undertaken in the Rutherglen district in Victoria, where the insect remains permanently established upon the roots of vines planted on resistant rootstocks. The behaviour of phylloxera on American vines was studied at the State Viticultural Nursery at Wahgunyah; here resistant rootstocks are produced, and a collection of American species of *Vitis*, and of their hybrids is maintained by the Department of Agriculture of Victoria.

The complete life-cycle was observed upon American vines. The incidence of leaf-galls was very variable. In a block of 480 vines of the *V.riparia* x *V.rupestris* hybrid 3309, galls occurred in the years 1954-58 inclusive at the following levels, expressed as a percentage of vines showing galls: 1·2, 25·8, 86·8, 0·8, nil. Galling was heavy in the summers of 1955 and 1956. In the latter year it appears to have been the most intense ever reported; in addition to 3309, sixteen other hybrid varieties exhibited galling. 3309 appears to be the most susceptible of all forms cultivated at Rutherglen, and carries galls in years when no other variety is affected. In the dry summer of 1958 galls were completely absent. The incidence of leaf galls appears to be related to the incidence and amount of summer rainfall; galling is facilitated by conditions favouring rapid shoot-growth and leaf-expansion, and implantation of crawlers; these may be killed by dry conditions or high temperatures before they become enclosed in gall tissue.

The root-living phases of *D.vitifolii* flourish in conditions of relatively high summer rainfall, as in 1955 and 1956. All the classical forms of root-deformation were observed. Nymphal alatae were found readily, and winged forms were produced freely in moist summer conditions. The eggs laid by alates were found under bud-scales, surface bark and elsewhere. The sexual forms were not located, but a single winter egg was found.

In autumn, larvae derived from eggs laid by root forms (radicicolae) select crevices in the bark of main roots, and enter diapause; they remain quiescent until the winter dormancy of the vine is completed when they become active and colonize the new season's roots.

Observations showed that the active root-forms can tolerate desiccation for brief periods only; it was concluded that under Australian conditions the transfer of phylloxera from place to place was most likely to be effected by means of rooted vines in the dormant condition, which carried diapausing hibernant larvae.

11. Studies of *Agrotis infusa* (Boisd.).

Mr. R. R. Rawat (Colombo Plan Scholar) completed a two-year study of the noctuid moth *Agrotis infusa* (Boisd.) as it occurs in South Australia. He dealt with the morphology and biology of larval and adult stages, and with their responses to various combinations of food, temperature and humidity.

12. Apicultural Investigations.

Professor J. E. Eckert, Professor of Apiculture in the University of California, spent the summer of 1957-58 in the Department of Entomology under a Fulbright grant. He made a general survey of the bee-keeping industry in Australia with respect to its methods, and its problems. With the assistance of Mr. Doull he studied the Kangaroo Island Ligurian bee, a form which was introduced from Italy about 1885 and which retains the characteristics of the original with little modification; this bee is used for queen-rearing by the Department of Agriculture of South Australia. The desirable features of the bee were assessed, and its freedom from Isle of Wight disease established. A set of standards, and a breeding schedule for use in the above programme were laid down.

Professor Eckert's work indicated that a number of problems of apiculture await investigation in South Australia; of these the problem of suitable substitutes for pollen in supplementary feeding was among the most important.

Plant Pathology

1. Advisory Services.

The Department continues to provide an advisory service to the State Departments of Agriculture and Woods and Forests. Among the specimens submitted, or in the course of field inspections, the following diseases were recorded for the first time in South Australia: red core of strawberry (*Phytophthora fragariae*), bacterial wilt of beans (*Corynebacterium flaccumfaciens*), late blight of tomato (*Phytophthora infestans*), downy mildew of cucumber (*Pseudoperonospora cubensis*), powdery scab of potato (*Spongospora subterranea*), and anthracnose of clover (*Kabatiella caulivora*). A number of plant parasitic nematodes also were recorded for the first time in South Australia. Some of the more important ones were *Pratylenchus coffeae* on apples, *Pratylenchus minyus* on cereals, *Rotylenchus buxophilus, Helicotylenchus nannus, Helicotylenchus erythrinae* on tomato, and *Pratylenchus pratensis, Radopholus* sp., *Tylenchus* sp. on native shrubs.

In general the plant disease position throughout the State remains much the same as described in previous reports, but the following changes have occurred. Downy mildew of lucerne (*Peronospora trifoliorum*) appears to have increased in incidence and has caused appreciable damage in many stands. Anthracnose of clover (*Kabatiella caulivora*) occurred in a few isolated areas in 1956 but was not apparent the following year. Black Spot (*Mycosphaerella pinodes*) and *Fusarium* wilt of peas have built up seriously in the Port Pirie and Renmark districts and are major problems to the industry. Aided by the wet season in 1956 early blight (*Alternaria solani*) caused heavy losses of tomatoes in the Port Pirie area. Potatoes grown from "seed" produced in the South-East of the State commonly developed purple top wilt virus symptoms. Black heart of apricots (*Verticillium* sp.) is becoming common in the Renmark-Cooltong districts and occurs in trees within a few years of planting. Citrus trees within or close to the flooded irrigation areas in 1956 which appeared to survive well have in some areas now begun to show symptoms of collar rot (*Phytophthora* spp.).

Quarantine inspections of plants imported from overseas were continued in association with the Department of Agriculture.

2. Legume Inoculation Service.

(Dr. J. H. Warcup and Mr. S. R. Hockley)

The demand for *Rhizobium* cultures increased again during the period under review, the biggest increase being for lucerne inoculum. Field experiments have shown that lucerne responds markedly to inoculation in many districts.

Strain trials of *Rhizobium* inoculation of strawberry clover showed that this clover can be effectively nodulated by rhizobia which are ineffective on red and white clovers.

In conjunction with the State Department of Agriculture, strain trials of *Rhizobium* inoculation of Mt. Barker subterranean clover and Hunter River lucerne were carried out on deep sands at Baker's Range, Lower South-East. Similar deep impoverished sands throughout the Upper and Lower South-East

have been impossible to establish in the past. The trials were carried out with and without lime to determine both the response to lime and the best *Rhizobium* strain for the particular pasture plants sown in these deep sands. A marked response to lime was shown but only the lucerne showed benefit from the *Rhizobium* inoculation. Mt. Barker subterranean clover showed a response to both lime and *Rhizobium* inoculation when sown on a problem soil in the Hundred of Duncan on Kangaroo Island.

Further trials with Western Australia blue lupin showed that satisfactory growth could be obtained by inoculation with a strain of *Rhizobium.*

3. Research.

(1) *Rhizoctonia Investigations* (Dr. N. T. Flentje and Dr. A. Kerr).

The opportunity arose in 1956-7 to compare the Australian strains of *Pellicularia filamentosa* and *Pellicularia praticola* with strains of the same fungi in Canada and United States of America. *P.praticola* was found to be widespread in both these countries and identical with the Australia form both in its cultural characteristics and pathogenicity. It was found to be carried on bean seed grown in the Western States of the United States, and was responsible for diseases of peas and beans.

The infection of a range of hosts by *P.praticola* at different temperatures was further studied, using strains of the organism obtained from Australia and the United States. The results were identical for all strains, infection occurring above 19-20°C in each host, the resulting stem rotting being more severe as temperatures increased above this level.

Growth rate studies were also carried out with isolates of both *P.praticola* and *P.filamentosa.* The optimum growth rate for the former was 28°C and of the latter was 24-25°C but the actual rates for the different isolates of each species varied considerably at these temperatures. In general, however, the growth rate of all isolates of *P.praticola* was higher than for *P.filamentosa.*

A new approach to understanding the taxonomic relationship of these species was commenced in collaboration with Dr. E. J. Hawn of the Canadian Department of Agriculture by using phase contrast microscopy to study nuclear behaviour in the growing hyphae. Counts of the number of nuclei per cell and a study of their behaviour in relation to branching and anastomosis are being made.

Further study of the infection process of these fungi on different hosts has been made and direct evidence has been obtained, for certain host-strain interactions, that root exudates from the host contain the material which causes infection cushion development by the fungus on the outside surface of the stem of the host. Infection cushion production is also governed by the nature of the host cuticle; it can be reproduced by placing strips of epidermis and cuticle from the host on a drop of the root exudate and inoculating with the appropriate strain of *Pellicularia.*

(2) *Fusarium Wilt of Peas* (Dr. A. Kerr and Mr. J. Nath).

Six varieties of peas imported from the United States of America appear to be resistant to *Fusarium oxysporum* f. *pisi* Race 2, but have proved unsuitable for commercial pea production in South Australia. A selected Greenfeast pea imported from New Zealand as resistant to the same *Fusarium* has proved susceptible to the disease when grown in South Australia. Breeding studies will

have to be undertaken to incorporate the resistance from the American varieties into peas suitable for growing under South Australian conditions.

Field and greenhouse studies have shown "Vapam" to be effective as a soil fumigant in controlling the fungi causing root rot and wilt of peas. Dosage rates and methods of application have been investigated in an attempt to find an economic method of using this treatment. The effect of "Vapam" on the general soil microflora and the recolonisation of treated soil is being studied in the laboratory.

(3) *Helminthosporium Investigations* (Dr. N. T. Flentje and Mr. R. J. Van Velsen).

Isolates of *Helminthosporium* causing root rot and leaf spot on cereals were obtained from widely separated localities in South Australia and four species were identified. The pathogenicity of several of these strains of the four species were tested on a wide range of wheat varieties. No resistance was observed but different isolates of *H.sorokinianium* varied considerably in their pathogenicity. Soil temperature, moisture and texture all affected the severity of root rotting on wheat.

Leaf penetration studies were carried out to determine the manner of infection, and the influence of humidity on conidial germination was investigated to determine what field conditions were necessary for aerial infection. Leaf exudates from cereals appeared to influence the germination of *Helminthosporium* conidia and subsequent formation of appressoria.

(4) *Urophlyctis on Subterranean Clover* (Dr. N. T. Flentje and Mr. H. L. Munasinghe).

The fungus *Urophlyctis* sp. causing galls on the stems, petioles, leaves and inflorescences of subterranean clover in many districts in South Australia, appears to be identical in all morphological characters with that recorded on lucerne. Infection studies on lucerne with this organism have, however, failed, suggesting there may be physiological strains of the organism. Specimens were forwarded to Dr. J. S. Karling in the United States and the techniques he has successfully used for germinating the organism will be used for further laboratory studies here.

(5) *Fungal "Gummosis" of Apricot* (Mr. M. V. Carter).

The perithecia of the "gummosis" fungus *Eutypa armeniacae* have now been found on dead wood of several woody plants including *Prunus amygdalus*, *Tamarix* sp. and *Vitis vinifera*. Isolates from dead wood of these hosts have all readily infected living apricot trees. Histological studies in the infection caused on apricot showed that the ascospores do not germinate on the surface of wounds, but are drawn down as far as 5mm. into the vessels. This may be the reason for failure to control infection by fungicides.

Data from spore trapping indicate that the ascospores are in greatest numbers in the air during spring and autumn with very low numbers during winter, and a field trial to determine the susceptibility of July wounded apricots to ascospore infection has been initiated.

(6) *Virus Investigations* (Dr. N. C. Crowley).

Investigation of virus diseases of grape vines in South Australia has been continued. Satisfactory transmission of at least some viruses to seedling vines

has been achieved. Seedlings from a variety of *Vitis labrusca* called Duke of Buccleugh at present appear to be excellent indicator material. Symptom expression is closely related to temperatures and symptoms are almost completely masked at temperatures above 72°F.

The virus diseases of cherries in the Adelaide hills have been transmitted to a range of *Prunus* species, but to date no real separation of the diseases has been achieved and a wider range of possible indicator hosts is being sought.

Investigations on the use of skim milk by tomato growers for preventing virus infection of tomatoes showed the treatment was not effective in the field, although skim milk has been found to be very effective as an inhibitor of virus infection.

Transmission of tobacco mosaic virus in the seeds of tetraploid tomatoes supports the theory advanced in a previous report that the infrequency of seed transmission results from inability of viruses to infect the haploid gametes.

The nature of resistance of peas to bean yellow mosaic virus was investigated by graft resistant to susceptible varieties. The reaction of both varieties remained unchanged. No significant qualitative differences in the amino acid content of susceptible and resistant varieties could be detected in this investigation.

(7) *Nematode Studies* (Mr. J. M. Fisher).

Surveys of plant parasitic nematodes in South Australian agricultural areas have been initiated following the appointment of a nematologist to the staff of the Department. The most important economic problems are caused by *Heterodera major* on cereals, *Meloidogyne* spp. and *Pratylenchus* spp. on a range of hosts including both vegetables and orchard trees. Population studies on these nematodes through the year are being continued in an attempt to relate soil populations with host damage. Methods of surface sterilising nematodes of the *Pratylenchus* group are being investigated in an attempt to develop techniques for laboratory investigations on pathogenicity.

(8) *Studies in the Micro-Flora of Australian Soils* (Dr. J. H. Warcup).

The ecology of fungi occurring in a pasture and adjoining wheat field at the Waite Institute has been studied. The results from the pasture area show a seasonal distribution of organisms similar to that found in the wheat field as mentioned in the previous report. Many apparently sterile fungi found in the soil mass also occurred in the pasture roots and apparently healthy roots bore organisms in their cortical tissue as well as on the surface, but not in the vascular tissue.

(9) *Mycology* (Dr. C. G. Hansford and Miss J. Brown).

The compilation of records of Australian fungi has been continued with records and material being forwarded from various parts of Australia. Further new species have been added and revision of the previous records has been carried forward. Valuable collections of higher fungi from his own personal herbarium have been deposited in the Waite Institute Herbarium from time to time by Professor J. B. Cleland.

The monograph of the Meliolaceae has been completed following the receipt of further specimens from overseas herbaria and the manuscript has been submitted for publication.

The structure, development and cytology of the Meliolaceae group has been investigated in an attempt to elucidate problems relating to the presence of sex

organs, ascogenous hyphae, paraphyses, the origin of the ascus itself and the number of nuclei in the spore cells. It appears that the first binucleate cell or "Ascogonium" is derived from the fusion of very rudimentary sex cells and from it binucleate ascogenous hyphae are developed which give rise to asci through crozier formation. Paraphyses also develop from these ascogenous hyphae but appear to have very little of their real function. In the spore there was usually only one nucleus but occasionally two nuclei per cell.

Climatology

1. Work has been done on a method, applicable to any region, of defining "growing period" in terms of monthly rainfall and temperature. A measure of the energy available for promoting growth during the growing period can then be given in terms of excess of temperature above a threshold of 40°F. This measure of "effective growth energy" can be used to classify agricultural climates. A provisional map has been drawn for Australia of isopleths of effective growth energy, and a world map is projected.

2. Previous work on the distribution of extreme values of meteorological elements is being extended.

3. A study has been made of air masses affecting the Adelaide plains during the summer season. For each month, the frequency of occurrence of each air mass has been determined, and the vapour pressure and daily run of temperature in each air mass ascertained. A brief analysis has been made of frequencies and durations of air mass spells. It was also found that most of the falls of rain of 20 points or more were associated with cold fronts.

4. An examination of Adelaide rainfall shows that it may be possible to indicate "settled" cycles with little variation of rainfall from year to year, and "unsettled" cycles with considerable fluctuations from year to year. During an "unsettled" cycle drought years and very high rainfall years may both occur.

5. Solar radiation received in certain Australian locations is being compared with that received in different parts of the world, with a view to defining radiation homologues.

Meteorological Records

Meteorological observations in connection with the work of the Waite Institute are being made at two centres: at the Waite Institute itself and at Yudnapinna (50 miles north-west of Port Augusta). Observations are made daily at 0900 local time. The records for 1956 and 1957, with climatological summaries, are given in Tables I to IV.

WAITE INSTITUTE (34° 58′ S., 138° 38′ E. *Height* 402 *ft.*)

Table I. Records for 1956 *and* 1957.

(a) Monthly rainfall and evaporation, number of wet days, mean relative humidity, and mean hours of bright sunshine per day.

Month	Rainfall (in.)		Number of days with ⩾ 0·04 in. rain		Evaporation (in.)		Relative Humidity 0900 local time		Hours of bright sunshine per day	
	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957
January	1·80	0·03	6	0	7·97	8·77	47	38	9·0	10·8
February	0	0·03	0	0	8·75	7·58	45	42	10·3	9·6
March	1·07	1·25	5	5	6·37	6·13	56	51	7·3	8·0
April	4·59	1·77	14	9	3·60	4·07	67	58	5·5	6·0
May	3·75	1·69	15	8	2·31	2·74	74	62	4·5	4·9
June	6·36	2·69	19	7	1·57	2·45	79	61	3·3	3·6
July	4·33	4·90	16	13	1·47	1·81	80	75	2·2	3·6
August	2·45	1·49	17	10	2·25	2·48	76	66	4·0	5·9
September	3·59	2·03	13	11	3·01	3·34	66	62	5·0	5·7
October	2·07	1·89	12	10	4·33	4·81	61	55	5·9	6·8
November	0·83	1·47	6	6	5·71	6·00	53	54	8·4	8·9
December	0·69	0·43	6	4	7·03	7·13	54	45	7·9	7·7
Year	31·53	19·67	129	83	54·37	57·31	63	56	6·1	6·8

(b) Mean of daily air temperatures; and extreme air temperatures (°F.)

Month	Mean daily				Mean ½ (Max. + Min.)		Highest		Lowest	
	Maximum		Minimum							
	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957
January	79·0	82·0	59·2	58·6	69·1	70·5	98	99	47	47
February	87·1	81·5	66·3	60·6	76·7	71·1	99	98	57	52
March	79·4	75·9	62·8	56·8	71·1	66·3	90	93	51	50
April	69·8	69·8	56·3	53·8	63·1	61·8	88	85	50	45
May	64·0	64·9	51·0	51·0	57·5	58·0	75	79	45	45
June	56·8	67·6	45·5	55·1	51·1	61·3	64	77	40	46
July	56·5	56·0	46·4	43·9	51·4	49·9	63	60	40	37
August	56·8	59·9	45·4	45·6	51·1	52·7	61	68	41	38
September	60·7	62·7	48·0	47·5	54·4	55·1	73	80	41	38
October	64·6	69·0	49·9	51·4	57·2	60·2	80	90	45	43
November	70·2	72·6	51·9	53·2	61·0	62·9	92	92	44	46
December	72·6	80·2	54·6	60·4	63·6	70·3	88	103	46	47
Year	68·1	70·2	53·1	53·2	60·6	61·7	99	103	40	37

(c) *Mean of daily soil temperatures (°F.) at 1 inch, 6 inches, 12 inches and 24 inches.*

Month	1 in. Maximum		1 in. Minimum		6 in. Maximum		6 in. Minimum	
	1956	1957	1956	1957	1956	1957	1956	1957
January	97·9	107·3	62·0	61·9	80·9	85·5	67·8	69·7
February	110·1	104·7	68·0	62·5	88·2	85·7	74·5	70·2
March	96·8	93·9	64·4	58·3	81·2	78·1	70·0	65·3
April	75·3	80·5	56·1	53·8	67·6	68·4	61·1	59·5
May	68·0	69·5	50·6	48·8	61·3	61·0	55·7	53·7
June	59·9	69·9	45·3	52·4	54·2	61·7	49·7	55·9
July	58·9	59·4	45·9	42·5	53·6	53·3	49·5	47·7
August	59·9	64·6	44·7	43·9	54·2	55·8	49·0	48·8
September	67·6	70·8	47·8	47·2	59·4	61·0	52·2	52·4
October	78·2	84·3	51·6	53·3	66·4	70·2	57·3	58·5
November	91·1	91·6	55·0	56·6	74·5	76·0	61·5	62·7
December	96·0	102·7	59·0	63·5	78·9	83·1	65·8	69·7
Year	80·0	83·3	54·2	53·7	68·4	70·0	59·5	59·5

Month	12 in. Maximum		12 in. Minimum		24 in. Maximum		24 in. Minimum	
	1956	1957	1956	1957	1956	1957	1956	1957
January	74·0	77·5	69·7	71·9	68·8	70·7	68·0	70·1
February	80·8	78·3	76·3	72·8	74·5	72·2	73·8	71·5
March	75·9	72·2	72·1	67·8	71·8	68·7	71·3	68·0
April	65·6	64·5	63·4	61·7	65·5	62·8	64·9	62·4
May	59·4	58·0	57·7	55·8	59·9	57·6	59·6	57·2
June	52·5	58·6	51·1	57·0	53·8	57·3	53·4	57·1
July	51·5	51·1	50·3	49·4	52·0	51·7	51·7	51·4
August	51·7	52·5	50·1	50·3	52·0	51·4	51·7	51·0
September	55·7	57·1	53·4	54·2	54·4	54·7	53·9	54·1
October	61·9	64·4	58·6	60·1	59·1	59·5	58·6	58·8
November	67·7	69·5	63·3	64·9	62·9	64·3	62·2	63·3
December	72·3	76·4	67·7	71·4	66·9	69·3	66·3	68·6
Year	64·1	65·0	61·1	61·4	61·8	61·7	61·3	61·1

(d) *Mean wind speed at 1·25 metres and 2 metres (miles per day)*

Month	1·25 Metres		2 Metres	
	1956	1957	1956	1957
January	82	79	99	96
February	83	74	97	89
March	68	69	81	84
April	86	72	102	89
May	52	57	64	71
June	67	59	84	73
July	58	57	74	71
August	84	65	102	80
September	72	78	94	95
October	79	80	95	96
November	73	85	90	102
December	78	75	95	90
Year	73	71	90	86

Table II. Climatological Summaries, 1925-57

Month	Rainfall (in.)	Days with ⩾ ·04 in.	Evaporation (in.)*	Relative Humidity 0900 L.T.	Saturation deficit (in. mercury) 0900 L.T.	Hours bright sunshine per day	Wind speed (miles per day)†	
							1·25 M.	2 M.
January	0·95	3·1	8·30	46	·423	9·0	88	101
February	1·08	3·1	6·88	50	·380	8·7	82	94
March	0·81	3·1	6·24	50	·353	7·7	76	88
April	2·16	7·8	3·81	60	·223	5·6	73	86
May	3·09	9·9	2·44	67	·155	4·2	66	78
June	3·20	11·8	1·64	74	·102	3·2	65	78
July	3·26	13·4	1·63	75	·091	3·2	68	80
August	2·94	12·4	2·19	71	·117	4·4	78	92
September	2·38	9·8	3·18	63	·172	5·7	79	94
October	2·20	9·0	4·44	59	·217	6·5	81	96
November	1·58	6·0	5·70	52	·296	7·7	84	99
December	1·17	4·7	7·37	48	·376	8·3	84	99
Year	24·82	94·1	53·82	60	·242	6·2	77	90

* Mean for 1935-57

† Mean for 1950-57

Month	Air temperatures (°F.)						
	Average daily			Average monthly		Extreme	
	Max.	Min.	Mean	Max.	Min.	Highest	Lowest
January	81·6	60·5	71·0	101·3	49·8	112	47
February	80·8	60·7	70·7	98·7	50·2	106	44
March	78·3	59·3	68·8	95·3	48·4	105	43
April	70·2	54·5	62·3	85·4	45·6	94	41
May	64·0	50·7	57·3	75·7	42·6	82	35
June	58·9	46·9	52·9	66·4	39·5	77	34
July	57·2	45·3	51·3	64·9	38·7	72	33
August	59·1	45·9	52·5	69·3	38·5	78	34
September	63·8	48·3	56·0	78·6	39·6	88	34
October	68·1	50·8	59·5	86·4	41·9	94	39
November	73·6	54·4	64·0	93·6	43·9	101	40
December	78·6	57·9	68·3	99·3	47·2	108	42
Year	69·5	52·9	61·2	103·6††	37·2††	112	33

†† Average annual max. and min. temperatures.

Month	Soil temperatures (°F.)							
	1 in.		6 in.		12 in.		24 in.	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	108·5	63·9	85·3	71·2	78·1	72·9	73·2	71·2
February	105·8	63·6	84·2	70·9	77·8	72·8	73·8	71·9
March	99·6	61·1	79·8	68·0	74·7	70·1	71·8	70·0
April	81·6	54·8	68·9	60·5	66·5	63·3	66·3	64·6
May	69·2	49·9	60·7	54·5	59·7	57·4	60·8	59·2
June	62·6	46·6	55·4	50·4	54·8	52·8	55·9	54·8
July	60·7	45·2	53·5	48·5	52·7	50·7	53·5	52·4
August	64·1	46·1	55·8	49·9	54·0	51·9	53·9	52·7
September	73·1	49·3	61·9	53·8	58·5	55·4	57·1	55·6
October	82·6	53·6	68·8	58·4	63·9	60·1	61·4	59·7
November	93·6	58·2	76·3	63·8	69·8	65·3	66·0	64·1
December	103·2	62·2	82·4	68·7	75·0	70·0	70·6	68·6
Year	83·7	54·5	69·4	59·9	65·5	61·9	63·7	62·1

YUDNAPINNA

(32° 8′S., 137° 10′E., Height 435 ft.)

Table III. Records for 1956 *and* 1957.

(*a*) *Monthly rainfall (in.), number of wet days and mean relative humidity.*

Month	Rainfall		Number of days with ⩾0·04 inches of rain		Relative Humidity (0900 local time)	
	1956	1957	1956	1957	1956	1957
January	0·0	0·0	0	0	43	34
February	0·68	0·05	3	1	50	40
March	0·03	0·21	0	3	55	47
April	0·17	0·13	2	3	56	55
May	3·00	0·10	6	1	75	56
June	1·19	1·01	7	3	83	66
July	3·71	0·75	11	6	88	77
August	0·58	0·28	4	3	76	63
September	0·61	0·35	5	3	57	48
October	1·73	0·82	4	4	55	41
November	0·22	0·07	2	1	41	46
December	0·01	1·16	0	3	34	40
Year	11·93	4·93	44	31	59	51

(b) Mean of daily air temperatures; and extreme air temperatures (°F.)

Month	Mean Daily				Mean ½ (Max. + Min.)		Highest		Lowest	
	Maximum		Minimum							
	1956	1957	1956	1957	1956	1957	1956	1957	1956	1957
January	91·3	90·3	61·1	63·0	76·2	76·6	111	110	50	39
February	94·6	91·2	67·1	62·4	80·9	76·8	108	106	62	54
March	86·0	84·4	61·9	56·0	74·0	70·2	94	97	55	42
April	76·0	76·9	52·6	50·7	64·3	63·8	92	90	43	43
May	67·8	71·2	48·5	45·6	58·2	58·4	77	84	43	34
June	59·2	71·0	42·6	47·5	50·9	59·3	70	78	37	40
July	59·7	58·6	42·6	39·7	51·1	49·2	68	65	36	33
August	61·3	64·9	40·4	42·3	50·8	53·6	67	79	35	33
September	67·2	71·8	44·2	44·7	55·7	58·2	82	87	33	37
October	72·5	80·2	48·2	52·9	60·3	66·6	87	106	39	42
November	81·6	87·1	54·0	57·0	67·8	72·0	101	103	44	49
December	86·5	91·8	49·9	63·8	68·2	77·8	100	114	35	55
Year	75·3	78·3	51·1	52·1	63·2	65·2	111	114	33	33

Table IV. Climatological Summaries, 1939-57

Month	Rainfall (in.)*	Days with ⩾ ·04 in.	Evaporation (in.)**	Relative Humidity 0900 L.T.	Saturation deficit (in. mercury) 0900 L.T.	Mean daily soil temperatures (°F.)†			
						1 inch		12 inch	
						Max.	Min.	Max.	Min.
January	0·54	1·6	14·52	44	·493	114·8	66·7	90·8	79·7
February	0·65	2·2	11·48	49	·412	109·0	65·2	89·2	77·9
March	0·46	1·7	10·34	49	·366	104·5	60·5	85·8	74·7
April	0·52	2·2	6·69	59	·221	88·4	53·0	75·8	65·7
May	0·85	3·4	4·25	68	·138	76·6	47·3	67·4	57·6
June	1·04	4·2	2·61	78	·075	66·2	42·0	61·1	50·6
July	0·70	4·4	2·93	77	·073	66·9	40·8	58·5	47·9
August	0·75	3·7	4·09	68	·119	73·0	44·2	61·4	51·6
September	0·65	2·9	6·44	53	·224	84·0	49·9	68·4	58·2
October	0·72	3·4	8·81	48	·301	92·4	55·8	75·0	63·6
November	0·58	2·9	11·09	44	·391	102·4	61·1	81·9	69·9
December	0·54	2·3	13·19	40	·494	114·7	65·3	87·9	76·7
Year	8·00	34·8	96·44	56	·276	91·1	54·3	75·3	64·5

* Mean for 1885-1957 ** Mean for 1935-54 † Mean for 1946-54 (9 years)

Month	Air temperatures (°F.)							Wind speed (miles per day) at 2 metres ¶
	Average daily			Average monthly		Extreme		
	Max.	Min.	Mean	Max.	Min.	Highest	Lowest	
January	92·2	63·5	77·8	109·1	52·9	117	39	167
February	89·5	63·4	76·4	105·3	53·9	111	49	166
March	85·7	58·9	72·3	99·5	48·2	109	41	130
April	75·6	51·8	63·7	91·2	42·4	99	36	102
May	68·5	46·3	57·4	81·9	35·8	88	27	79
June	62·8	41·9	52·3	71·6	33·6	78	24	76
July	61·3	39·3	50·2	71·2	30·9	79	21	77
August	65·6	40·9	53·2	78·1	32·4	88	26	93
September	72·4	45·1	58·7	87·8	35·8	97	29	111
October	77·2	50·7	63·9	95·4	39·9	106	35	118
November	83·7	55·9	69·8	101·7	44·6	111	40	133
December	89·5	60·4	74·9	107·6	49·4	114	35	141
Year	77·0	51·5	64·2	111·3††	29·5††	117	21	117

†† Average annual max. and min. temperatures.

¶ Mean for 1951-4.

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Records of Field Experimental Work

I. PERMANENT ROTATION EXPERIMENT, 1926-1957. (C1)

Effect of different crop rotations on the yield of wheat.

Variety of crop and seed rate per acre: Sepoy wheat (1926-34), Seewari (1935-47), Seewari 48 (1948-57), 80-90 lb.; Early Burt oats, 60-70 lb.; Prior barley, 70-80 lb.; White Brunswick peas, 120-150 lb.; Wimmera rye-grass, 10-15 lb. (1926-45), and Wimmera rye-grass, 3 lb. + Fulghum oats, 40 lb. (1946-57) on the rotations wheat, pasture, fallow and wheat, oats, pasture, fallow; Wimmera rye-grass, 3 lb. + subterranean clover, 6 lb. on the rotations wheat, 2 years of pasture and wheat, 2 years of pasture, fallow; phalaris, 3 lb. + subterranean clover, 6 lb. + lucerne, 1 lb. + Wimmera rye-grass, ½ lb. on the rotations wheat, wheat, 4 years pasture, and the permanent pasture.

Basal dressing of superphosphate, 187 lb. per acre (1929-42), 94 lb. per acre (1944-57).

Design: Unreplicated, but each course of each rotation is represented each year.

Area of each plot = 1/7 acre (1926-37), 1/7·619 acre (1938-57). Total yields are based on air-dry weights of harvested crops and oven-dry weights of forage crops.

TABLE 1

MEAN YIELDS OF CROPS IN EACH ROTATION IN 1956 AND 1957, AND OVER THE DURATION OF THE EXPERIMENT. (FIGURES IN BRACKET INDICATE THE NUMBER OF YEARS FOR WHICH REPRESENTATIVE YIELDS ARE AVAILABLE.)

Rotation	Grain, bushels per acre				Total produce, cwt. per acre*				
	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
1956									
Wheat, fallow	9·0	—	—	—	16·6	—	—	—	—
Wheat, peas	9·7	—	—	6·9	14·2	—	—	9·7	—
Wheat, barley, peas	27·3	19·1	—	18·7	29·6	19·7	—	26·8	—
Wheat, oats, fallow	14·8	—	14·5	—	20·7	—	18·7	—	—
Wheat, pasture, fallow	18·1	—	—	—	22·5	—	—	—	13·5
Wheat, 2 years pasture: 1st year	27·8	—	—	—	33·5	—	—	—	6·0
2nd year	—	—	—	—	—	—	—	—	61·8
Wheat, 2 years pasture, fallow: 1st year	24·2	—	—	—	32·3	—	—	—	25·1
2nd year	—	—	—	—	—	—	—	—	71·4
Wheat, oats, pasture, fallow	21·4	—	27·0	—	27·5	—	28·6	—	20·5
Wheat, wheat, 4 years pasture: 1st year	19·2	—	—	—	28·3	—	—	—	22·4
2nd year	23·6	—	—	—	28·7	—	—	—	86·7
3rd year	—	—	—	—	—	—	—	—	82·8
4th year	—	—	—	—	—	—	—	—	69·2
Wheat continuously	8·0	—	—	—	10·7	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	128·5

* Air-dry weights of harvested crops, oven-dry weights of forage crops.

I. PERMANENT ROTATION EXPERIMENT, 1926-1957. (C1)—*continued.*

Rotation	Grain, bushels per acre				Total produce, cwt. per acre*				
	Wheat	Barley	Oats	Peas	Wheat	Barley	Oats	Peas	Pasture
1957									
Wheat, fallow	29·6	—	—	—	35·3	—	—	—	—
Wheat, peas	19·0	—	—	9·5	25·0	—	—	18·2	—
Wheat, barley, peas	38·4	26·1	—	16·8	46·1	23·1	—	30·0	—
Wheat, oats, fallow	32·2	—	20·7	—	41·8	—	18·4	—	—
Wheat, pasture, fallow	39·5	—	—	—	48·5	—	—	—	13·7
Wheat, 2 years pasture: 1st year	23·3	—	—	—	30·7	—	—	—	3·9
2nd year	—	—	—	—	—	—	—	—	23·1
Wheat, 2 years pasture, fallow: 1st year	59·5	—	—	—	73·1	—	—	—	28·8
2nd year	—	—	—	—	—	—	—	—	36·2
Wheat, oats, pasture, fallow	48·9	—	37·7	—	63·2	—	28·0	—	16·8
Wheat, wheat, 4 years pasture: 1st year	1·9	—	—	—	5·9	—	—	—	16·5
2nd year	15·2	—	—	—	19·3	—	—	—	38·9
3rd year	—	—	—	—	—	—	—	—	60·3
4th year	—	—	—	—	—	—	—	—	48·2
Wheat continuously	5·9	—	—	—	11·7	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	63·1
Mean yield to 1957									
Wheat, fallow	30·7(32)	—	—	—	44·9(32)	—	—	—	—
Wheat, peas	23·3(32)	—	—	17·6(30)	33·6(32)	—	—	26·9(32)	—
Wheat, barley, peas	27·0(6)	20·8(6)	—	14·3(6)	29·2(6)	21·2(6)	—	25·2(6)	—
Wheat, oats, fallow	31·9(31)	—	34·4(31)	—	48·8(31)	—	34·2(31)	—	—
Wheat, pasture, fallow	36·7(31)	—	—	—	51·2(31)	—	—	—	26·0(30)
Wheat, 2 years pasture: 1st year	31·1(6)	—	—	—	36·7(6)	—	—	—	17·4(6)
2nd year	—	—	—	—	—	—	—	—	45·3(6)
Wheat, 2 years pasture, fallow: 1st year	37·8(6)	—	—	—	47·9(6)	—	—	—	40·2(6)
2nd year	—	—	—	—	—	—	—	—	71·5(5)
Wheat, oats, pasture, fallow	43·1(30)	—	45·1(30)	—	61·1(30)	—	41·7(30)	—	28·7(30)
Wheat, wheat, 4 years pasture: 1st year	19·3(6)	—	—	—	31·3(6)	—	—	—	39·2(4)
2nd year	15·0(5)	—	—	—	20·8(5)	—	—	—	77·5(4)
3rd year	—	—	—	—	—	—	—	—	84·8(4)
4th year	—	—	—	—	—	—	—	—	71·7(4)
Wheat continuously	12·7(32)	—	—	—	23·8(32)	—	—	—	—
Permanent pasture	—	—	—	—	—	—	—	—	96·7(6)

* Air-dry weights of harvested crop, oven-dry weights of forage crops.

TABLE 2

YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1956 AND 1957. (OVEN-DRY WEIGHTS, CWT. PER ACRE.)

Rotation	Total	Sown Species					Volunteer Species		
		W.R.G.	Sub. Clover	Phalaris	Lucerne	Grazing Oats	Annual Legumes	Annual Grass	Miscellaneous
1956									
Wheat, pasture, fallow	13·5	3·3	Tr.	—	—	10·2	—	—	Tr.
Wheat, 2 years pasture: 1st year	6·0	2·5	0·4	—	—	—	—	2·4	0·7
2nd year	61·8	27·3	11·4	0·3	Tr.	—	—	4·3	18·5
Wheat, 2 years pasture, fallow: 1st year	25·1	6·5	5·8	Tr.	—	—	—	6·0	6·8
2nd year	71·4	25·5	17·7	1·8	—	—	—	15·4	11·2
Wheat, oats, pasture, fallow	20·5	2·5	—	—	—	7·5	7·1	—	3·4
Wheat, wheat, 4 years pasture: 1st year	22·4	2·6	Tr.	Tr.	—	—	—	11·3	8·4
2nd year	86·7	23·1	17·4	3·8	—	—	—	27·3	15·1
3rd year	82·8	8·3	Tr.	37·1	—	—	—	36·8	0·5
4th year	69·2	4·9	1·5	13·2	—	—	—	47·4	2·2
Permanent pasture	128·5	11·3	9·4	33·2	1·3	—	—	68·4	4·7
1957									
Wheat, pasture, fallow	13·7	Tr.	—	—	—	13·7	—	—	Tr.
Wheat, 2 years pasture: 1st year	3·9	3·4	Tr.	Tr.	—	—	—	0·5	—
2nd year	23·1	2·0	Tr.	0·7	—	—	—	3·9	16·4
Wheat, 2 years pasture, fallow: 1st year	28·8	19·4	1·5	—	—	—	—	7·9	Tr.
2nd year	36·2	18·0	2·9	0·4	—	—	—	11·5	3·4
Wheat, oats, pasture, fallow	16·8	Tr.	—	—	—	16·8	—	—	Tr.
Wheat, wheat, 4 years pasture: 1st year	16·5	3·2	2·8	0·2	2·0	—	—	2·2	6·1
2nd year	38·9	1·3	Tr.	7·7	—	—	—	27·7	2·2
3rd year	60·3	4·0	0·8	5·3	Tr.	—	—	46·2	4·0
4th year	48·2	0·6	Tr.	16·6	—	—	—	30·0	0·8
Permanent pasture	63·1	0·4	1·3	7·3	3·8	—	—	36·7	13·6

II. INFLUENCE OF GRAZED AND HARVESTED FORAGE CROPS ON THE YIELD OF TEMPORARY PASTURE AND WHEAT IN FOUR-COURSE ROTATIONS, 1937-1957. (C53)

Rotations from 1949 onwards.

1	2	3	4	5
Fallow Wheat Fallow Wheat	Fallow Wheat Oats Pasture†	Fallow Wheat Oats* Pasture†	Fallow Wheat Peas Pasture†	Fallow Wheat Peas Grazing Oats

*With sulphate of ammonia added. †Wimmera rye-grass.

Variety of crop and seed rate per acre; Seewari 48 wheat, 80-90 lb.; Mulga oats, 60-70 lb.; White Brunswick peas, 120-150 lb.; Fulghum grazing oats, 60-70 lb.; Wimmera rye-grass, 10 lb.

Fertilizer: Basal superphosphate applied at 1 cwt. per acre. Sulphate of ammonia at 2 cwt. per acre applied to oats on rotation 3 at seeding.

Design: 60 main plots in 4 groups of 15 plots, each group representing one course of the rotations. The groups of 15 plots are divided into 3 randomized blocks in which each rotation is represented by a plot. The plots are subdivided into halves; one half the forage crop is grazed and on the other it is harvested.

Area of main plots = 1/6·94 acre.

Yields are based on air-dry weights of harvested crops, and oven-dry weights of forage crops.

TABLE 3.

MEAN YIELD OF CROPS FOR EACH ROTATION IN 1956, AND FOR THE PERIOD 1949-56.

Rotation	Management of 2nd course	Grain, bushels per acre			Total produce, cwt. per acre*			
		Wheat	Oats	Peas	Wheat	Oats	Peas	Pasture
1956								
Wheat, fallow	grazed	7·1	—	—	17·1	—	—	—
	—	5·9	—	—	14·7	—	—	—
Wheat, oats, pasture, fallow	grazed	25·0	—	—	26·5	7·5	—	3·6
	harvested	18·1	10·2	—	19·8	7·5	—	4·1
Wheat, oats+S/A, pasture, fallow	grazed	27·9	—	—	28·3	39·0	—	5·3
	harvested	19·0	44·2	—	20·6	47·4	—	4·0
Wheat, peas, pasture, fallow	grazed	32·9	—	—	31·9	—	27·7	8·6
	harvested	20·7	—	10·4	24·2	—	16·5	6·8
Wheat, peas, grazing-oats, fallow	grazed	28·0	—	—	31·3	17·9	27·1	—
	harvested	21·5	—	14·2	24·1	15·1	17·1	—
1949-56								
Wheat, fallow	grazed	21·7	—	—	29·9	—	—	—
	—	20·0	—	—	28·5	—	—	—
Wheat, oats, pasture, fallow	grazed	28·9	—	—	35·2	8·9	—	6·5
	harvested	26·2	9·6	—	32·5	7·8	—	4·8
Wheat, oats+S/A, pasture, fallow	grazed	33·1	—	—	39·7	34·6	—	10·0
	harvested	28·3	38·5	—	34·2	37·3	—	5·0
Wheat, peas, pasture, fallow	grazed	38·8	—	—	48·5	—	36·9	23·4
	harvested	32·2	—	18·7	41·1	—	24·7	17·4
Wheat, peas, grazing-oats, fallow	grazed	38·7	—	—	49·8	39·5	41·4	—
	harvested	34·5	—	23·2	43·9	31·8	28·9	—

*Air dry weights of harvested crops, oven-dry weights of forage crops.

TABLE 4.

YIELD AND BOTANICAL COMPOSITION OF PASTURE PLOTS, 1956 (OVEN-DRY WEIGHTS, CWT. PER ACRE)

Rotation	Management of 2nd course	Total yield	Spp. cut	
			W.R.G.	Miscellaneous
Wheat, oats, pasture, fallow	grazed	3·6	2·9	0·7
	harvested	4·1	3·4	0·7
Wheat, oats+S/A, pasture, fallow	grazed	5·3	4·4	0·9
	harvested	4·0	3·5	0·5
Wheat, peas, pasture, fallow	grazed	8·6	5·6	3·0
	harvested	6·8	5·4	1·4

III. INFLUENCE OF PASTURES AND FORAGE CROPS ON THE YIELD OF WHEAT GROWN IN ROTATIONS OF VARYING DURATION (C92

Combined field crop-pasture rotational experiment begun in 1947 with the object of comparing two-course and four-course rotations and an eight-) course rotation, based on (1) Fallow, wheat; (2) Peas (grazed), wheat; (3) Pasture for two years, fallow, wheat; (4) Pasture for three years, wheat; (5) Pasture for six years, wheat, wheat.

The field has previously been subjected to a long period of wheat, bare fallow; and the investigations provide scope for examining the effects of the rotations on the nitrogen status and physical properties of the soil, as well as on forage and crop production.

Variety of crop and seed rate per acre; Seewari 48 wheat, 80-90 lb.; White Brunswick peas, 120-150 lb. Pasture mixture of Bacchus Marsh subterranean clover, phalaris, Wimmera rye-grass, lucerne. Basal superphosphate 112 lb. per acre per annum with each season of crop and of pasture.

All five of the rotations were commenced in each of the three seasons 1947, 1948, 1949. Those begun in 1949 were originally established in 1946 but not proceeded with until 1949; they thus had an advantage of three seasons rest from cropping, and this is apparent in the yields from this set.

Total of 30 plots, each 2·00 × 0·40 chains (1/12·5 acre), made up of rotations (5) × seasons (3) × replications (2).

TABLE 5.

MEAN YIELDS OF CROPS FOR EACH ROTATION (GRAIN, BUSHELS PER ACRE; TOTAL PRODUCE, CWT. PER ACRE)

Rotation		Yields for each year										Mean Yields		
		1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	Peas	Pasture	Wheat
Fallow, wheat	Wheat		25·0(a)	37·0(b)	15·3(a)	20·8(b)	13·8(a)	16·9(b)	28·9(a)	11·3(b)				
					43·6(c)		48·8(c)		29·8(c)		18·4(c)			25·8
Peas, wheat	Peas	77·2(a)	50·6(b)	18·5(a)	11·7(b)	59·1(a)	57·2(b)	53·8(a)	34·0(b)					
				18·7(c)		47·6(c)		53·6(c)		38·2(c)		43·3		
	Wheat		30·5(a)	37·0(b)	12·8(a)	17·9(b)	24·5(a)	23·5(b)	26·4(a)	25·2(b)				
					33·8(c)		47·8(c)		30·6(c)		30·9(c)			28·4
Pasture, pasture, fallow, wheat														
Pasture: 1st year		35·1(a)	29·7(b)	55·1(c)		25·7(a)	27·0(b)	53·1(c)					37·6	
2nd year			76·0(a)	43·0(b)	51·8(c)		74·0(a)	67·6(b)	71·0(c)				63·9	
Wheat					42·3(a)	28·5(b)	41·2(c)		50·1(a)	26·5(b)	43·3(c)			38·7
3 years pasture, wheat														
Pasture: 1st year		33·3(a)	38·5(b)	54·3(c)		15·5(a)	12·7(b)	35·7(c)					31·7	
2nd year			73·3(a)	45·8(b)	50·0(c)		69·5(a)	53·3(b)	70·2(c)				60·3	
3rd year				53·3(a)	51·6(b)	120·9(c)		75·9(a)	86·0(b)	93·6(c)			80·2	
Wheat					38·1(a)	21·3(b)	42·7(c)		35·9(a)	21·4(b)	28·8(c)			31·4
6 years pasture, wheat, wheat														
Pasture: 1st year		34·7(a)	33·0(b)	53·2(c)									40·3	
2nd year			72·9(a)	38·1(b)	53·8(c)								54·9	
3rd year				45·6(a)	38·2(b)	115·4(c)							66·4	
4th year					53·7(a)	56·0(b)	80·1(c)						63·3	
5th year						112·4(a)	68·8(b)	78·9(c)					86·7	
6th year							75·2(a)	83·7(b)	89·2(c)				82·7	
Wheat	1st year							14·4(a)	27·4(b)	19·7(c)				20·5
	2nd year								22·1(a)	4·5(b)	26·0(c)			17·5

(a) Rotations begun 1947 (b) Rotations begun 1948 (c) Rotations begun 1949